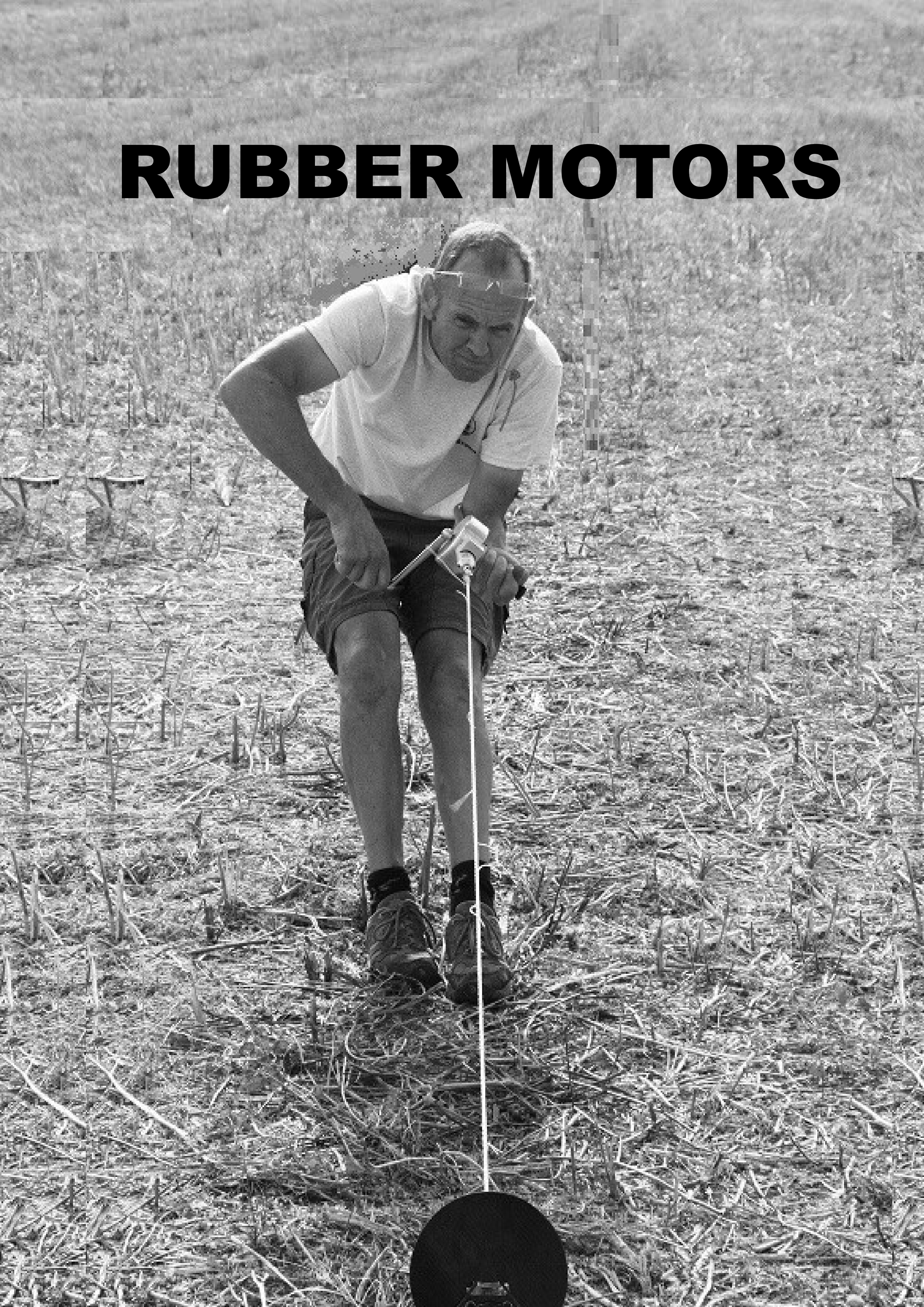
RUBBER MOTORS



RUBBER MOTORS

The articles here are taken from Aeromodeller and Model Aircraft magazines from the 1950s to the '70s. Please bear in mind that the maximum rubber weight for F1B Wakefields has changed over the years and that the brands of rubber referred to in the articles are no longer available, but the principles remain the same.

As well as the re-prints here, there is more information as follows in the form of some of the papers in various BMFA Free Flight Forum Reports. All are still available: http://freeflight.bmfa.org/free-flight-forum. Other information is in Symposium Reports of the US National Free Flight Society.

A Method for the Qualitative Assessment of Indoor Rubber Motors	Bernard Aslett	1989
The Physical Behaviour of Rubber Strip Motors to F1B Specification and the Effects of Heat Treatment on Performance	Ron New	1989
Rubber - Use and Abuse	Mike Evatt	1993
Selecting Slippery Stuff	John Barker	1997
Rubber Ramblings Take 2	Bernard Aslett	2001
A New Method of Rubber Testing	Bernie Hunt	2003
Rubber Density Measurement	George Waby	2005
Getting More Out of Rubber	John O'Donnell	2005
Taking the Tension Out of Winding—or Does It?	Mike Evatt	2007
Practical Rubber Testing	Mike Woodhouse	"
Rubber Motor Testing for Indoor Duration Models	Clive King	"
Beyond Rubber Stretch Testing	Peter King	2008
Testing Coupe Motors	Peter Hall	2010
A Knotty Problem	Peter Hall	2013
The Making and Testing of F1B Rubber Motors	Peter Brown	2016

… and from the NFFS Symposium Reports

Tan 2 Rubber - A Journey	John Clapp	1999
The Elastic Band is the Beating Heart of the Wakefield	Dick Blackam	2003
Rubber Energy Output	Fred Pearce	2003
Rubber Testing	Ron Pollard	2004
Energy Testing and the Performance of Rubber Powered Models	Fred Pearce	2008
Rubber Mechanics	Aram Schlosberg	2011
Rubber Testing	Tapio Linkosalo	2012
Rubber Testing - Myths and Realities	Paul Rossiter	2016
Computerized Rubber Testing	Carroll Allen	"

RUBBER MOTORS ON TEST

Bench tests using an electronic counter enable Wakefield expert RON WARRING to give a new slant on an old subject with emphasis on the respective merits of "straight" or "geared" rubber motors.

From Aeromodeller, June 1952

Extravagant claims have been made concerning the respective merits of "taut" and " slack" motors. There has been a certain amount of practical evidence to support the idea that a rubber motor which is supported between hook distances equal to its unstretched length, delivers more power- two typical examples being that a simple helicopter model performs best with a taut motor (a longer motor needing a greater cross section for equivalent performance); and also Wakefields with" taut" motors, either geared or long-fuselage single skein type, apparently have a better performance. In the writer's experience, for example, a geared Voodoo (Zombie development) out-performs a single skein Voodoo with the same weight and cross section of rubber. Climb is markedly better, motor run longer and height reached greater. Yet against these practical results is the thought that the same weight of rubber motor, however used, should be capable of delivering the same, or nearly the same, amount of useful work or energy.

Pretty obviously the answer would not come from flight test data alone. There are far too many variables, not the least being the improbability that flight time is an exact measure of true performance at anyone time. In other words, flight duration alone is no acceptable standard for comparison, owing to the variable" weather" element. Flight performance is, of course, still the "end product", as it were. If enough flights are made in relatively still conditions it is soon quite easy to judge the still air performance of any particular model.

Over, say, five or six flights of an evening, and without altering the trim, a given number of turns should consistently produce the same flight time on the majority of occasions. Any marked differences may be put down to the air sinking or rising at the time of that particular flight. Yet there are some evenings when the air is consistently rising slightly, just as on other evenings the reverse conditions may apply. Thus a single evening's test results may be misleading, even if the air is apparently "dead". The more"still air" flying you do the nearer you can get to consistent figures, but the whole business is a very lengthy process.

Consistent test results, therefore, are more likely to come from indoor experiments, measuring the actual power output of the motor instead of the flight performance of the model. The classic method of doing this, of course, is to measure the torque with an apparatus something like that sketched in Fig. 1 which gives instantaneous readings of torque as the motor is unwinding. Some experimenters vary this by winding on a certain number of turns a test reading, letting off a counted number of turns, stopping the propeller and taking a second reading, and so on.

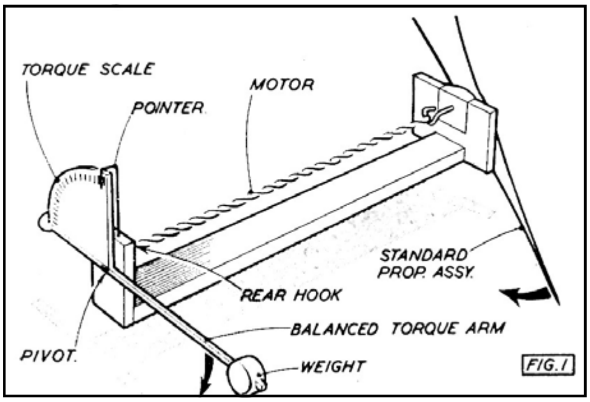


FIG. I

The second method is open to several objections. In the first place it does not simulate true working conditions. Torque output, in a model in flight, is given by an unwinding motor and this may be quite different from that of the same motor with the turns let out step~by-step.

The normal torque curve of an unwinding motor is shown in Fig. 2, representing, say, the motor wound to 1,000 turns and torque readings taken every 5 seconds as the motor is unwinding all the time. Suppose, now, the same motor is wound to 500 turns and the test repeated. The second curve will not start at the "500 turn"

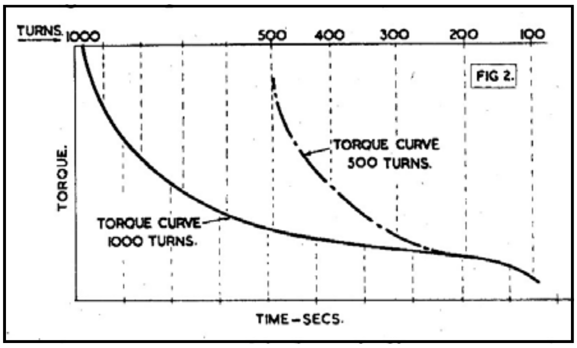
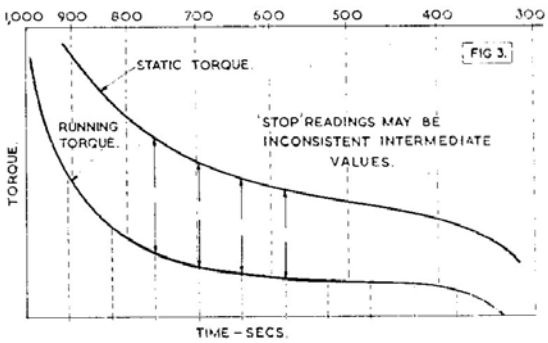


FIG 2.



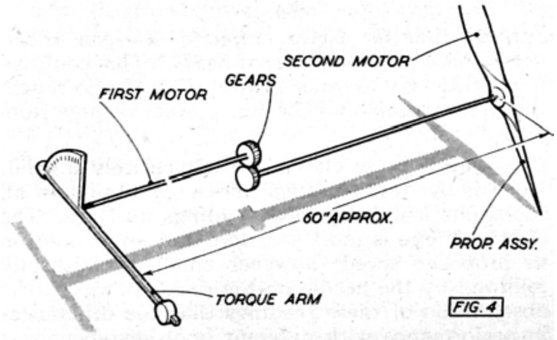
mark on the previous curve, but at a very much higher level, tapering off into the original curve, as shown by the dotted line. Other tests at different turns would give a series of similar curves. The step-by-step method is measuring not the torque output of the motor under working conditions, but a series of initial torques on these various curves-or some intermediate value between the two-so that the curve plotted-Fig. 3-is of doubtful value.

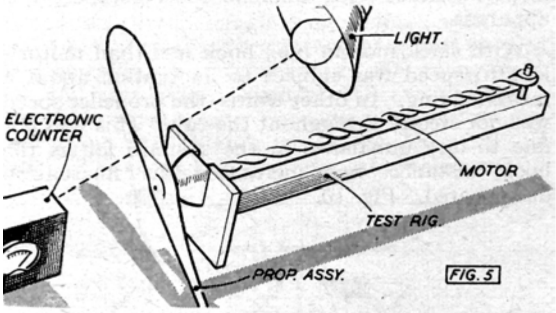
After trying gears for the first time in July 1951 and obtaining (apparently) "something for nothing" from the motor, the writer determined to test out this set-up on the bench. The original reason for the adoption of gears was not in seeking a "better" or "improved" power output but merely to eliminate bunching troubles with a 4-oz. motor by halving it taut between hooks. In a fuselage of conventional length, return gears were the logical solution.

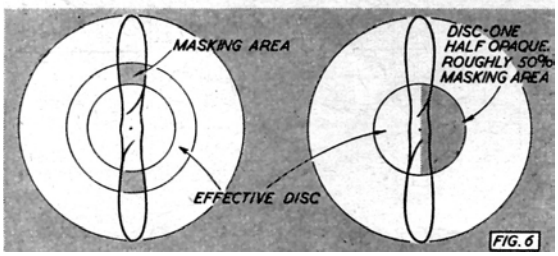
It was fairly obvious that the existing torque testing apparatus was not particularly suited for dealing with a return-gear system. Hitherto all torque readings had been made off the rear end of the unwinding motor with a standard propeller assembly on the front end of the motor. Adapted for gears the test rig would have to take the form of Fig. 4, which would not necessarily duplicate working conditions with motors in the model.

There was also another aspect of the problem. Gears run in a series of short bursts-not because of their friction but because one end of a rubber motor unwinds differently to the other end. A number of tests with a marker bound in the middle of a rubber motor showed that the centre of the motor unwound erratically-just like the gears burst into action and then stop. The implication was that measuring the torque at the rear end of the motor may not exactly duplicate the torque applied to the propeller shaft, i.e., the force rotating the propeller and generating thrust.

It was finally decided that measurement of the speed of rotation of the propeller was the best



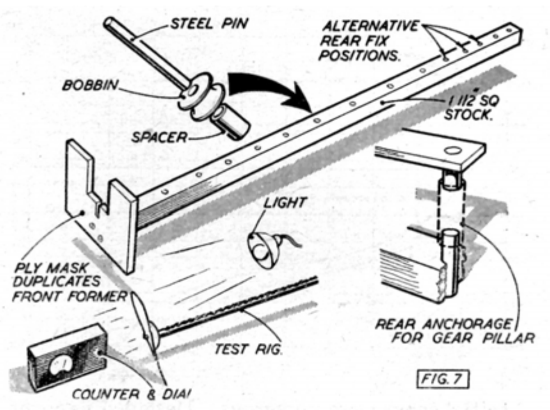




solution, since this could be done without putting any load at all on the system. by using a light beam and a photo-electric cell. Since the problem had entered the realm of electronics, co-operation of the Hook brothers of R/C fame was enlisted, they assuming responsibility for the design and construction of the electronic rev. counter.

The apparatus is shown simply in Fig. 5. The counter itself is a small self-contained unit which is placed just in front of the· propeller. Behind the propeller is a suitable light source (a torch was satisfactory, although actual tests were made with a 100-watt lamp) shining into the photocell "window". The propeller and motor assembly was quite separate and could be of almost any form -e.g. even a standard fuselage. The apparatus counted the frequency with which the light beam was interrupted by the revolving propeller blades and registered speed as a simple micro-ammeter scale reading. Scale readings were related to actual r.p.m. by a series of check tests with constant speed discs.

Initial snags were numerous. Designed to cover a specific range of speeds (roughly 15 revs. per sec. down, as representative of Wakefield propeller performance), giving a top scale reading at maximum speed and as near as possible a linear scale, both parties forgot, for a start, that at 10 revs. per sec., for example, the actual time of interruption of the light beam was extremely small because the masking area-i.e., the blade width-represented only a small proportion of the actual disc area-Fig. 6. As a result the counter became very critical as regards the quality and position of the light source when measuring the higher speeds. If this was not just right, then it registered nothing at all on the dial. A lot of time was wasted trying to overcome this failing until the obvious answer of fitting a small disc to the propeller itself-one half blackened and the other half clear-occurred. This completely cured the original sensitivity and made every part of the apparatus non-critical as regards adjustment. And since the same disc attached to the same prop. was used throughout the tests, any effect this disc had on propeller performance can safely be ignored. In actual fact it probably has no effect at all as far as propeller speed is concerned for static running. The final test apparatus is then shown in Fig. 7.

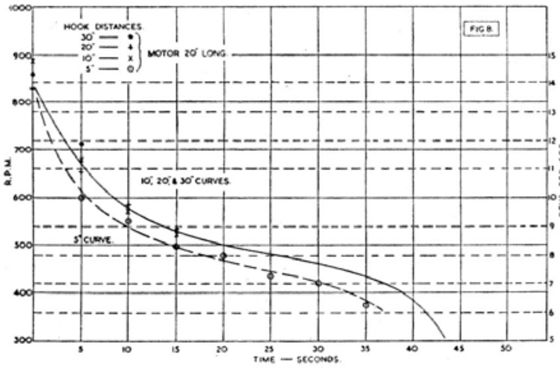


The beam is marked off with a series of "hook distances", drilled to take a steel pin at each of these points, to which the rear bobbin of the test motor, or gear assembly, can be located. Speed was read off as micro-ammeter readings and translated into r.p.m. by reference to a calibration graph.

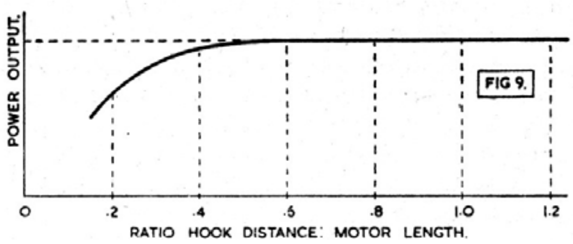
TEST RESULTS

The first series of tests have now been completed and make interesting reading. The test motor was 20 ins. long, comprised of 14 strands of Pirelli 1/4-in. strip rubber, as typical of Wakefield practice. Power output, as represented by the speed at which it turned the propeller, was determined at hook distances of 5, 10, 20 and 30 ins. Provision was made for testing at closer intervals, but this was not done for reasons which will be obvious.

All motors were wound to the same number of turns, this number of turns being the maximum possible consistent with no fatigue. In other words, well broken-in rubber was used and the test runs used were the highest possible consistent with a control motor on separate tests showing identical power output over a number of tests, wou~d to this figure, tested, wound once more, tested, and so on. The turns figure possible was 20 turns per inch, i.e., 400 turns on the 20-in. test motor,

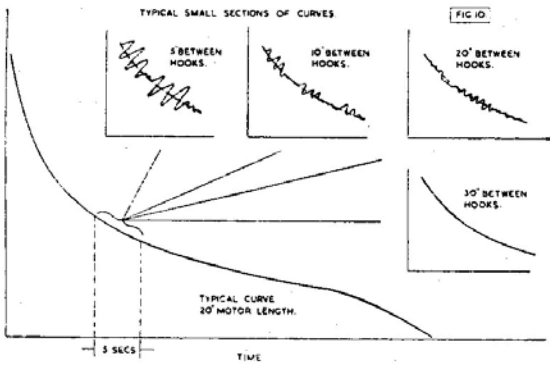


Now the result of these tests is plotted out in graphical form in Fig. 8. Except for one, performance is virtually the same. The exception is where the hook distance is 5 ins. or one quarter the length of the motor. Here the wound motor is so cramped and knotted that a definite slowing up is apparent. Within reasonable limits, however, it appears that the power output of a motor is independent of distance between hooks. This could be represented by another graph-Fig. 9. So much, then, for claims for better power output from taut motors.

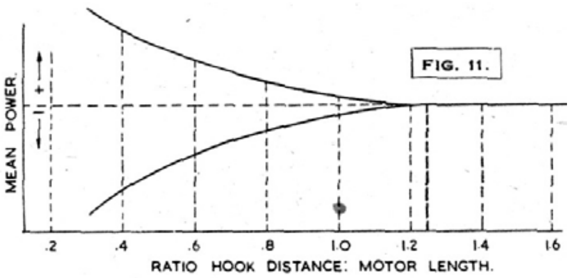


However, these claims are not entirely invalid. Even if the test readings were very similar in all cases, one feature of these readings was not. The electronic eye is most sensitive and any variation in propeller speed, however small, is faithfully followed by the needle on the dial. It was in the observation of these readings that the differences in performance with different hook distances was apparent.

With slack motors (i.e., hook less than motor's length) speed was subject to fluctuation about a mean reading. In 'other words, the propeller speed was not steady throughout the run. This was not due to any unbalance in the system, for as the hook distance was increased this fluctuation disappeared. Fig. 10.



The taut motor is very nearly smooth running - not exactly so, but much smoother than the same motor on shorter hook distance. When the hook distance is still further increased so that the motor is actually tight between hooks, all unevenness eventually disappears. This is realised at a hook distance of approximately 1·25 times the motor length - Fig. 11.

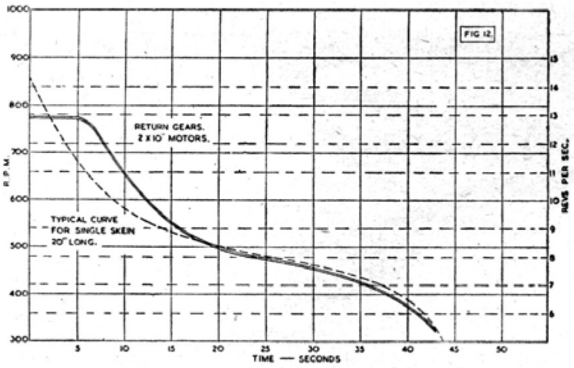


This gives a clue to the answer of the original problem. Any advantages offered by a taut motor are most certainly due to its smoother running characteristics. Power output, as such, is substantially the same. What almost certainly does occur-and this is a feature beyond the scope oi the present tests-is that the shorter the distance between hooks the more uneven the unwinding of the motor.

Even if the motor does not bunch in the accepted sense, the same thing appears to take place in a smaller scale all the time with slack motors. This would account for those otherwise inexplicable "poor" performances to which the best of rubber models are subjected at times.

The inference is, of course, that a model with taut motors should be more consistent and the writer's own experience with geared models seems to bear this out. Or, alternatively, the greater the ratio motor length:hook distance, the more care necessary to avoid bunching, such as anti-bunch fittings and very careful winding technique.

The remaining tests were made with a geared motor-the 20-in. single skein motor split into two 10-in. motors with a return gear unit as used in a model, and now wound to 200 turns each, i.e., 400 turns total, as before. This was to give a direct comparison between single skein and return gear drive performance which was known to be different from practical flying performance.



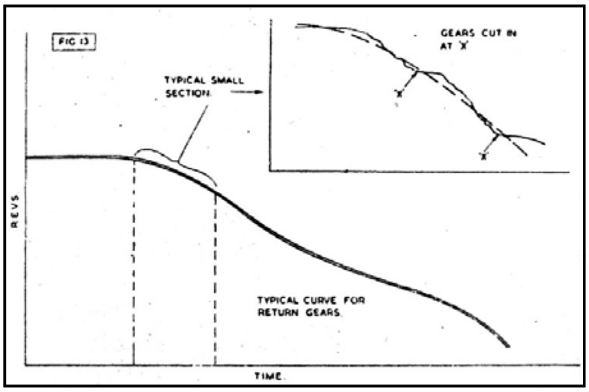
Perhaps starting with an impression of what was thought would be the difference led to rejection of the first test, but subsequent tests confirmed the initial readings. Fig. 12.

The initial part of the output curve is now completely modified and no longer have we the characteristic "torque curve" which drops sharply, tapers off to a flattish portion and then dies away again. Initial power output is definitely lower and for more than five seconds on every test remained at a constant figure. After that the curve drops away again, but slowly, and eventually merges, more or less, with the single skein curve.

Now this is most interesting, for it implies a constant power output for the initial part of the flight, with an initial power of less than that of a single skein motor. In other words, it should be easier to control and also give a most definite improvement in climb over the first fifteen seconds or so. Remember, here, the test motors were short, and if the same curves were reproduced for, say, 30-in. motors, improved climb characteristics for up to fifty seconds might be expected. Towards the end of the power run the geared drive seems to give rather less power than a single skein motor.

It must also be remembered that these tests were conducted with "straight" motors, i.e., the single skein motor was not tested in the corded condition, this being the subject of some further tests. What it does indicate, however, is that with taut motors, geared return provides a better initial power run than the same length of motor between hooks in a long fuselage.

One question the test with the geared drive did solve - the effects of the "spurts" of power as the gears cut in periodically, feeding the bottom motor into the top one. As far as propeller speed is concerned there is no acceleration. What happens is that from an initial steady reading speed begins to waver slightly, as indicated by the dial needle. Quite suddenly the gears cut in and immediately the speed is dead steady once more, to repeat the process throughout the power run - Fig. 13. The gear feed does, as previously surmised, produce a "stepped" power run, but no increase in propeller speed as the gears come in. Particularly over the first part of the power run the propeller speed is more appreciably constant than with a single skein drive, and then descends in a series of steps.



GETTING THE BEST OUT OF YOUR RUBBER

Aeromodeller, January 1954

The rubber-driven model is still the best introduction to "power" flying. Relatively cheap, simple to construct and amazingly consistent, once properly trimmed and given the right care and attention. Once trimmed, a well constructed good design should stay trimmed. The one factor which may remain variable, however, is the rubber motor.

A lot of nonsense has been written about rubber motors, tending to over-emphasise the failures which may occur if elaborate care and attention is not given to the motor. At the same time there is more than a modicum of truth in the assertion that rubber is not always as consistent as it could be.

The basic facts are these. Normally, rubber of the same brand or specification can be expected to give a consistent performance. In other words, if you are using a certain brand of rubber, then new supplies of this same brand can reasonably be expected to have comparable performance characteristics. However, most rubber strip is produced in batches (strip is actually made up in sheet form and cut down to strip lengths after vulcanisation). If the specification or make-up of the original rubber mixture is not carefully controlled from batch to batch, some difference may be experienced from skeins of different age. These small variations in the composition may be within limits accepted by the manufacturers as normal to their production methods. Absolutely fresh rubber, too (i.e. straight from the manufacturer) is seldom as consistent as aged rubber. After manufacture, rubber characteristics generally tend to improve with storing-up to a period of six to twelve months.

Sometimes, variations in the heat-treatment process necessary to harden the rubber produces a batch which is not uniformly cured. As a result, the physical characteristics of the rubber may vary somewhat from end to end of a single skein. When this occurs, rubber taken from one end of a skein may be denser than rubber from the other end. In other words, if a number of motors are made up from this skein each to the same length, the weights, and the power characteristics, of the motors may vary slightly.

Another possible cause of difference is a definite change in the original rubber mixture specification where the manufacturers may decide to try some other ingredient, or alter the proportions of the original specification to enhance certain properties. The properties improved· may be beneficial, or completely the opposite as far as the application of the resulting strip to aeromodelling is concerned.

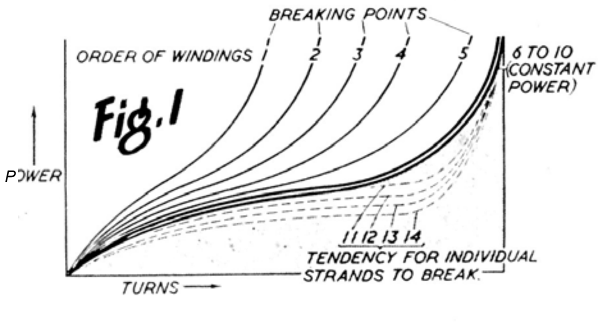
These possible variations concern the contest modeller principally, since he is always seeking rubber strip which gives the greatest possible power output for a given weight as a primary characteristic; and rubber which has a good physical strength as a secondary characteristic. We put performance before durability of the rubber for contest work, since it is not uncommon for modellers to adopt a principle of "one motor-one flight" in important contests.

The main advantage of changing a motor each flight would appear to be a psychological one-a fresh motor should give peak performance whereas a used motor may have fatigued and will consequently give less power. Usually, however, the rubber motor is far more blameless than even expert modellers give it credit for. A bad flight with a poor climb from an otherwise high performance model may well be due to adverse weather conditions prevailing at the time, rather than the rubber motor "tiring", or a broken strand. As a point of interest here, static torque tests have failed to detect any difference in power output from a wound motor with up to four of its 16 strands broken, provided the loose ends are "caught up" and thus bound in with the bulk of the wound motor.

RUNNING-IN

Ultimate performance of the rubber motor will, almost entirely, depend on the way in which it is run-in. Like an internal combustion engine, a rubber motor cannot be expected to develop full power from its initial winding up. Unlike an engine, however, a "fresh" motor develops more power until run-in. It cannot be wound up to anything like its potential maximum turns without breaking.

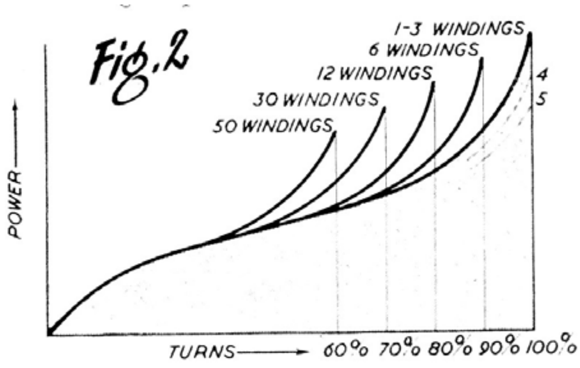
If the motor is simply made up to length and installed in the model it cannot initially be wound up to, say, about half potential maximum turns without fear of breaking. Its corresponding power output will be high, but its duration of run short. For the second winding, the turns that can be put on are some 20 per cent higher, and so on, stage by stage, until the potential maximum is reached.



In other words, if we had some sort of device which would indicate when the motor was about to break, turns and power output corresponding to successive initial windings would take a pattern similar to those shown in Fig. 1. Continue with more windings and the maximum turns possible would now no longer increase. During this series of windings, too, the power output curve would be identical for each winding. After a certain number of windings, again, maximum turns would still stop at the same level, but the power output curves would gradually get lower and lower. The rubber motor has now become fatigued and its useful life is over.

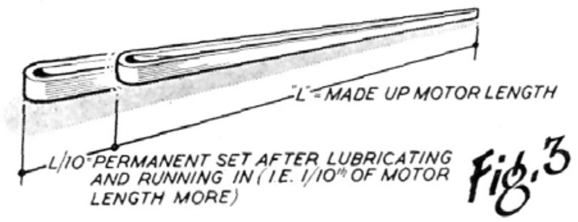
A proper run-in period is essential with all new rubber made up into motors, first to develop its capabilities to take a maximum number of turns and second to bring it to the state where it will give a constant power output. The "constant power" stage corresponds to the normal useful life of that motor.

It is also interesting to note how the number of "useful life" windings varies with the number of turns applied to the motor. Properly run-in and then wound to maximum turns each time, motors may show signs of fatigue after only three windings - Fig. 2. Wound to 90 per cent. turns each time, "useful life" winding may be double that number, or more. Wound to only 80 per cent. maximum turns each time, "useful life" is doubled again. These are only rough figures, but indicate that "full turns" windings do drastically reduce the useful life of a rubber motor.

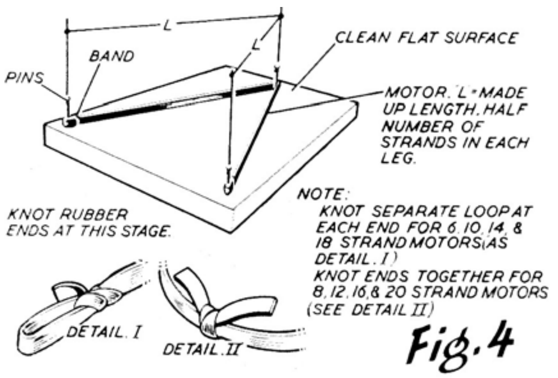


What the graph does not show is the mechanical failure of the motor on repeated high-turn windings. Individual strands are more prone to break, calling for constant repairs. Normally this does not affect the "useful life" figure, but it is annoying to find strands breaking during winding up, generally calling for a change of motor to be on the safe side. When one strand "pops", quite likely others are beginning to part and the whole motor may break suddenly if winding is proceeded with.

Dealing now with the practical side of making up and running a new motor, there are two main factors to be considered-the number of stages in which the motor should be run-in and the increase in length or permanent stretch the rubber will have after running in. Fresh rubber, properly run-in, has a permanent deformation equivalent to about 10 per cent. of its original fresh length' - Fig. 3. In other words, if you made up a 30-in. motor from fresh rubber, ran it in stages and then re-measured its length, this final length would be about 30+3=33 ins. It should remain at that normal length for the rest of its useful life. The amount of permanent stretch is independent of the number of strands. The permanent stretch must be taken into account in making up the motor length.

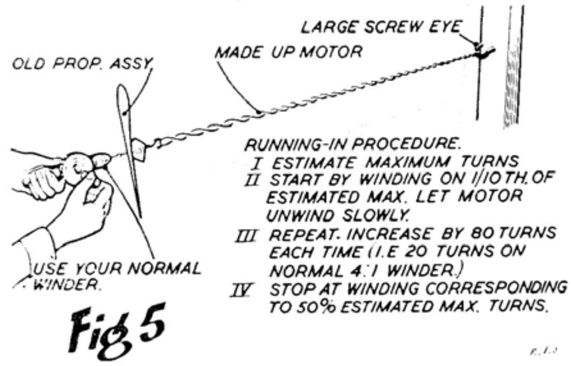


The best way to make up a new motor is to lay it out in two "legs" over any clean, flat surface, as shown in Fig. 4, having calculated the normal length of motor required. Each "leg" comprises one half of the required number of strands in the finished motor. If the motor has to be made up to a definite weight, the resulting length can be calculated from Table I, noting that lubricant increases rubber weight by about 1/12th. Rubber ends should be knotted permanently at this stage and the motor ends bound with a rubber band.



The motor should now be removed from the layout board and lubricated. Ordinary castor oil is a satisfactory, if messy, lubricant. Proprietary lubricants based on a soft-soap-glycerine mixture are normally regarded with more favour. The latter do provide slightly better lubricating action, as exemplified by the fact that knots can be tied to hold in rubber lubricated with castor oil, but the same knots will not hold on soap-lubricated rubber. With soap lubricant, any knots which may be necessary in the lubricated strip must be bound, preferably with wool.

The motor is now ready for running in. An old propeller assembly should be used for this, the rear end of the motor being looped over any suitable fitting. A door knob is widely favoured for the latter, although a large screw eye fitted to the workshop door frame is generally better-Fig. 5.

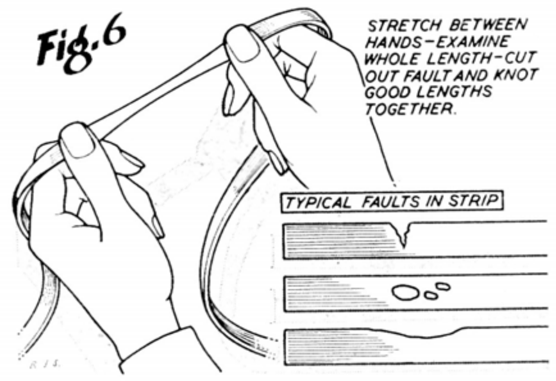


The optimum number of strands for running-in fresh rubber is a matter of controversy. If the stages are few in number (which gets the job over quicker!) there is more danger of the rubber breaking up. A particularly safe process seems to be to start with only ten per cent. estimated maximum turns and then work up, increasing the number of turns by a maximum of 80 each time (i.e., 20 turns on a 4:1 winder) up to some 80 per cent. of the estimated maximum. There is no real need to go beyond this point, unless the motor is intended for a short contest life on "near maximum" turns, when a final winding to 90 per cent. maximum turns should be done, after an accurate determination of the actual breaking turns on a spare motor.

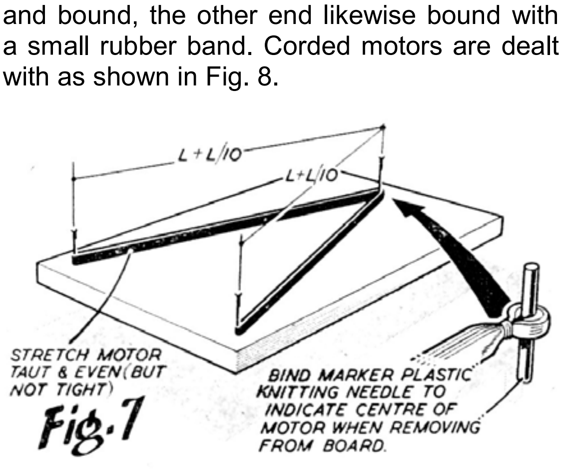
It is quite possible that a strand or two may be broken during the running-in process. This does not necessarily mean that the rubber has inferior mechanical properties. The broken strands can be re-tied and the motor will be quite satisfactory, although it would be commonsense precaution to reject the motor if more than, say, one quarter of the total number of strands broke during running-in.

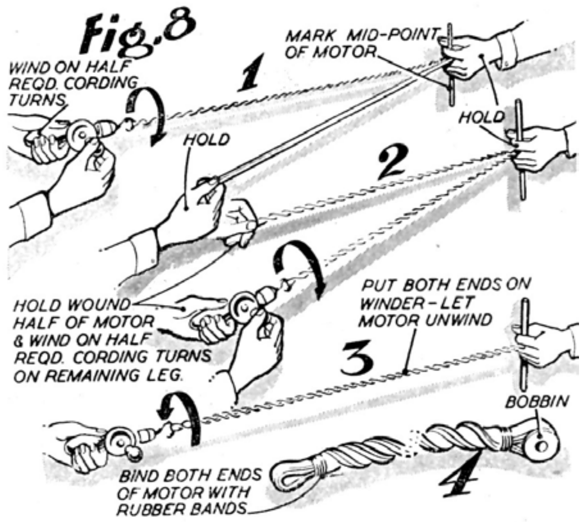
There is also the chance that the whole motor will break during the process. This happens with the best of rubber strip. Sometimes with three or four motors made up from the same skein one will break completely during prewinding, another will break a strand or two and the others will show no signs of breakage. The danger point for complete breakage appears to be when running-in reaches the stage 50 to 60 per cent. full turns. Provided the motor takes up to 80 per cent. maximum turns during the running-in it can be relied upon to take at least these turns on the field and considerably more, provided it is not completely over-wound.

EXAMINATION
After running-in, the motor should be inspected carefully along its entire length, pulling a single strand stretched between finger and thumb of one hand, well stretched, as in Fig. 6. This will indicate points of potential failure-nicks started in the edges or imperfections in the strip itself. The rubber must be cut at this point and re-knotted. If made up for use without such a check, strands are almost certain to break at these points on an early winding. Some rubbers are particularly prone to faults of this nature-others are remarkably free of mechanical imperfections.



The run-in, checked motor is then laid out over the marking board again-Fig. 7-re-adjusting the length of the" legs" to account for the permanent stretch achieved during running-in. With a "taut" motor the two ends are brought together and bound, the other end likewise bound with a small rubber band. Corded motors are dealt with as shown in Fig. 8.





Washing of the new rubber strip before lubricating has not been mentioned-simply because it is not necessary. It is sufficient to shake off any chalk adhering to the rubber. Nor is washing off the lubricant necessary after the motor has been used. Lubricant can stop on for a whole season, re-lubricating at intervals as required. Motors can also be left corded for weeks at a time without suffering any apparent ill effect, although the areas covered by the rubber band (end) binding should be re-lubricated before use. Normally, however, corded motors are unwound after a day's flying and re-corded again the evening before the next flying session.

STORING THE MOTOR
Sensible care of the made-up, run-in motor consists of keeping it free from grit and dirt and storing it in a clean container (e.g., a plastic or glass jar) between flying sessions. Motors should not be left in a model from one week to another as this tends to dry out the lubricant. Good rubber, properly run-in, however, is surprisingly resistant to abuse and will seldom let you down if treated with adequate care. However, never take risks with unknown motors.

COMPARATIVE TESTS
For simple "static" comparison of new motors, simply timing the power run on a given number of turns and comparing with the length of run on the same propeller and a proven motor with the same number of turns is a useful check. If the new motor gives a longer run, then almost certainly it is weaker than the original motor. If a shorter power run, a more powerful motor. This test, of course, must be applied after the new motor has been run-in.

Another practical check is the "feel" of the motor during the winding stages associated with running-in. With enough experience this becomes a most valuable guide. During the running-in windings, though, a motor always feels more powerful than when wound on the field, partly because it is more powerful at this stage and successive windings, increasing the number of turns each time, is more tiring than a single winding. The "feel" check is most likely to detect a weak motor.

The best check of all, of course, is a flight test on the model on each new motor. This need not be carried out on high turns. Most rubbers of the same brand, good or bad, follow a similar power output curve. Knowing the still air flight time on, say, half turns will soon indicate whether they are "up" or "down" on the original. Once again, of course. the new motors must be adequately run-in for this check to have a real significance.

The danger associated with running-in a new motor in the model, during actual flights, is that you may break the rubber at some stage. The destructive characteristics of a broken motor are too great to court lightly. For the same reason, high-turn flying in contests should be restricted to a working maximum which has been checked as on the safe side by a destruction test on a similar motor, preferably under similar conditions. Extreme cold tends to harden rubber and reduces the maximum turns possible. Extreme humid heat can also lead to premature breakage and, more likely loss of power. Modellers in tropical areas are well aware of the short expectancy of life for their rubber motors; but similar humid conditions, though to much less a degree, can prevail in Europe, and must be guarded against with the use of reduced max. turns.

RUBBER ON TEST

by Ron Warring and Bob Copland

From Model Aircraft, April 1954

The test data given in the following pages was obtained from typical samples of commercial rubbers available namely Dunlop and Pirelli. In view of the significance of rubber power under the new Wakefield contest rules, test motors were made up to Wakefield size in each case.

Restricting rubber weight to a maximum of 2.82 ounces under the new Wakefield rules places a premium on rubber performance, and also renders the actual making-up of the motor a little tricky. .It is difficult to measure rubber accurately by length-accurate enough, that is, to work· right up to the limit allowed under the Wakefield rules. Measuring out a motor by weight is the obvious solution, but then makes it very difficult to sub-divide the skein so measured into the required number of strands.

A practical solution is to aim at making up a motor slightly undersize, so leaving that little margin for possible error. What you may lose in power output this way can safely be ignored. Thus a Wakefield motor made up to 2 5/8 ounces dry weight is a good standard size. Lubricant will then add a further five per cent. or so, making the total weight of the motor between 2 11/16 and 2 5/8 ounces, on average - comfortably within the weight limit.

TABLE I. PHYSICAL DATA SPECIMEN RUBBER STRIP

BRAND	Nominal cross section (in.)	Actual cross section (in.)	Actual cross section area (sq. in.)	Average density (oz./cu. in.)	Lengths for 2⅝ oz. (Av.)
Dunlop	¼ × 24	0.248 × 0.042	0.0104	0.56	37 ft. 8 in. (40 ft.)*
Dunlop	3/16 × 24	0.188 × 0.042	0.0079	0.56	49 ft. 6 in. (53 ft.)*
Pirelli	¼ × 24	0.242 × 0.045	0.0109	0.565	35 ft. 9 in. (38 ft.)*
Pirelli	3/16 × 24	0.175 × 0.042	0.0074	0.56	54 ft. (58 ft.)*

*These figures are approximate lengths for maximum size motors.

TABLE II. MAKE-UP LENGTHS (IN INCHES) FOR WAKEFIELD MOTORS. (Approx. 2¾ oz. lubricated)

RUBBER	NUMBER OF STRANDS 12	14	16	18	20	22	24
Dunlop ¼ ...	37½	32	28¼	—	—	—	—
Dunlop 3/16 ...	—	—	37½	33	30	27	24½
Pirelli ¼ ...	36	31	27	—	—	—	—
Pirelli 3/16 ...	—	—	40½	36	32	29½	27

TABLE IIA. APPROX. MOTOR LENGTHS WHEN RUN IN. (2¾ oz. motors, well lubricated)

RUBBER	NUMBER OF STRANDS 12	14	16	18	20	22	24
Dunlop ¼ ...	42	36½	32	—	—	—	—
Dunlop 3/16	—	—	42	37	33½	30½	27½
Pirelli ¼ ...	39	34½	30	—	—	—	—
Pirelli 3/16 ...	—	—	45	40	35½	32½	30

A number of sample motors were measured out to a dry weight of 2 5/8 ounces and their average physical dimensions taken to provide the data summarised in Table I. Allowing for the fact that there is often a slight variation in density between different skeins of the same brand, and sometimes even between different ends of the same skein, motors cut to the length indicated should, when lubricated and made up, come safely. within the weight limit. The higher figures in brackets indicate lengths to which the rubber should be cut to end up with a lubricated rubber closer to the limit.

Table II reduces these figures to layout dimensions for making up motors of different cross section, substantially correct to the nearest half inch. After breaking in, the motor will have stretched somewhat, due to its taking up what is termed a permanent set, and if it is necessary to re-make the motor at this stage corresponding lengths will be approximately as summarised in Table IIa.

Various specimen motors were then broken in carefully and winding continued to find a nominal maximum turns figure. By this is meant the motors were not actually wound to destruction but as tight as possible without them actually breaking. Many factors affect actual breaking turns, such as temperature, condition and age of the rubber, individual winding techniques, etc. Also, of course, maximum turns will be reduced if the motor is roped or corded. Allowing for such factors, the figures in Table III should be obtainable with similar rubbers, although for safety a working maximum about ten per cent. lower would be advised. Table III data is reduced to equivalent terms for standard Wakefield motors of various cross sections in Table IV.

TABLE III. NOMINAL MAXIMUM TURNS
(Turns per inch)

RUBBER	NUMBER OF STRANDS 12	14	16	18	20	22	24
Dunlop ¼ ...	25	22.5	20	17.5	—	—	—
Dunlop 3/16 ...	—	30	26	23	21	20	18
Pirelli ¼ ...	27	24	21	18.5	—	—	—
Pirelli 3/16 ...	—	—	31	28	25	22	20

TABLE IV. NOMINAL MAXIMUM TURNS
(2⅝ oz. rubber)

RUBBER	NUMBER OF STRANDS 12	14	16	18	20	22	24
Dunlop ¼ ...	940	720	565	—	—	—	—
Dunlop 3/16 ...	—	—	970	760	630	540	440
Pirelli ¼ ...	970	740	565	—	—	—	—
Pirelli 3/16 ...	—	—	1,250	1,000	900	650	540

TABLE V. APPROX. MOTOR EQUIVALENTS BASED ON CROSS-SECTION AREA

RUBBER	EQUIVALENT STRANDS					
Standard Max. 24 (Dunlop & Pirelli)	12	13	14	15	16	18
Dunlop 3/16 ...	16	17	18 (18½)* 19	20	21 (21½)* 22	24
Pirelli	17	18	20	21½	23	—

*Geometric equivalent.

The data in Table V is intended only as a general guide. It does not follow that the power output of a motor is directly proportional to the cross sectional area of the rubber, although if the rubber were of identical form and constitution in each case, this should hold true. (Theoretically torque or power is proportional to cross section$^{1.5}$. Table V can, however, indicate what size of motor might be a good alternative choice to, say, a 14 strand 1/4in. motor which is a little too weak, or a little too powerful. In such a case, 18 strands of 3/16in. Dunlop would give slightly less cross section, 19 strands of 3/16 in. slightly more cross section.

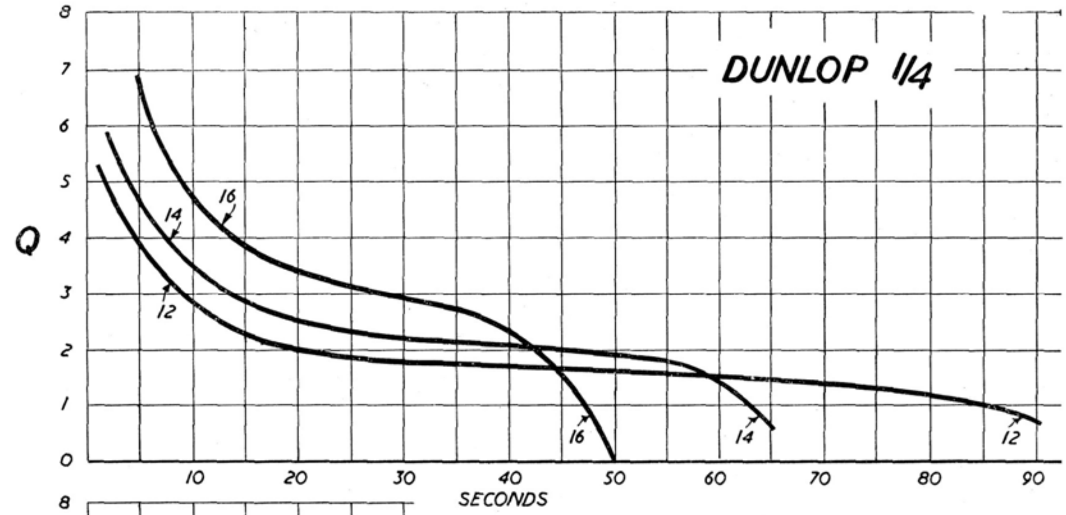
Such general conversion should, however, be studied in conjunction with the characteristic torque curves of the four different rubbers tested.

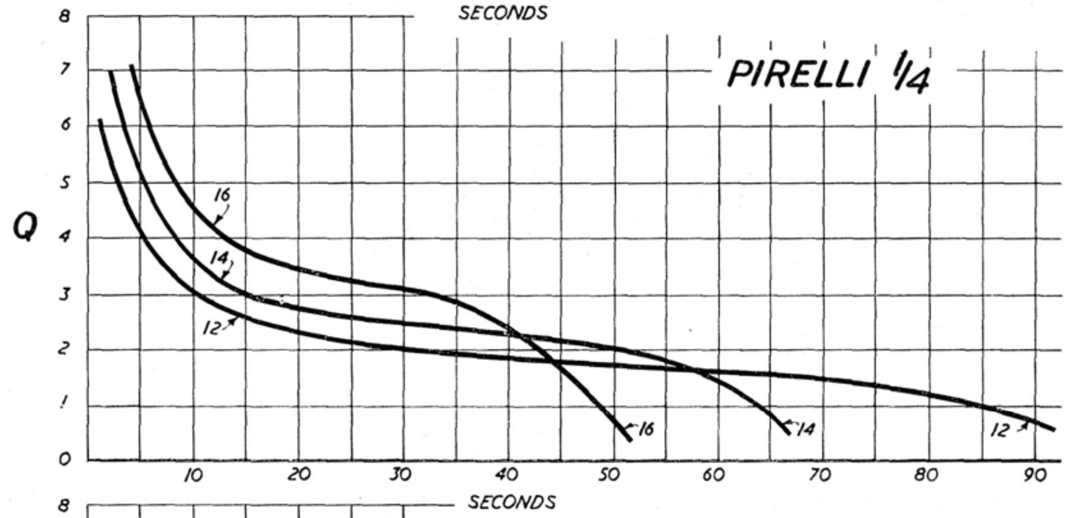
The torque curves were obtained by carefully running-in sample motors of the appropriate size, up to about go per cent. nominal maximum turns. They were then rested and torque test readings taken with each motor, in turn, made up into three different arrangements – 12, 14. and 16 strands in the case of 1/4-in. strip; and 16, 18 and 20 strands in the case of 3/16-in. strip. These motor sizes embrace the whole range likely to be required in a Wakefield model. The same motor was used for each of the three separate tests appropriate to that particular size and brand. This eliminated any possibility of variation between different motors of the same brand and size. The possibility of fatigue affecting the results was also eliminated by winding all motors to 80 per cent. nominal maximum turns for the purpose of testing, whatever size they were made up into. At 80 per cent. maximum turns, fatigue effects are almost negligible until after the sixth or seventh winding, and often delayed for a dozen.

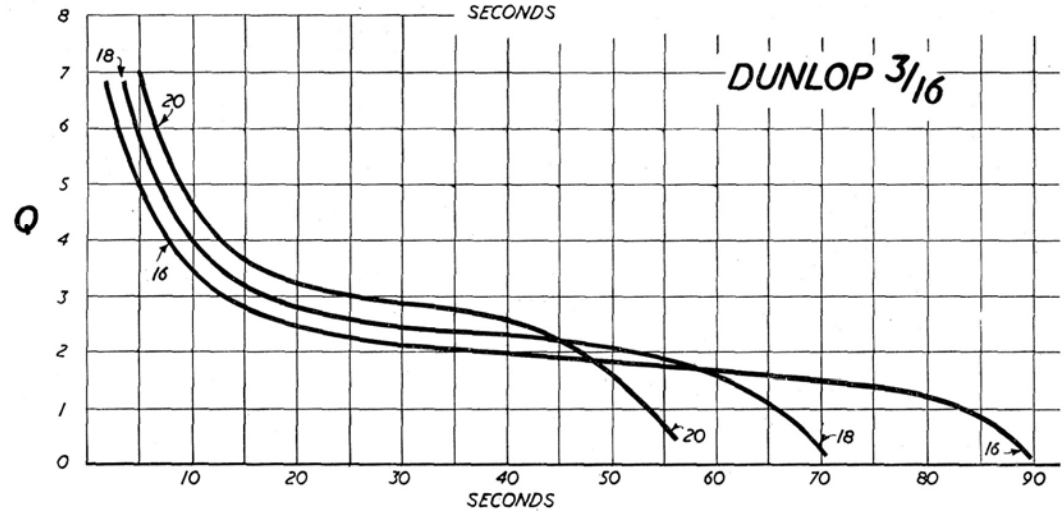
Since we have no simple means of using actual torque figures generated (e.g. torque measured in ounce-inches), torque is quoted with regard to an arbitrary linear scale ranging from 0 to 8. The scale being linear, figures are truly proportional to actual torque and so can be used as a basis for direct comparison. To assist in this all four graphs have been drawn to an identical grid pattern.

For each brand and strip size, three separate curves are shown. These correspond to the test motor being made up into the number of strands indicated and with each corresponding motor then wound to 80 per cent. of its nominal maximum turns. The load in each case was the same-a 19 in. diameter 30 in. pitch Wakefie1d propeller of conventional form and blade area.

It is not the purpose of this article to comment on the comparative performances of the different brands and strip sizes concerned. This can be done by individual readers, bearing in mind their particular requirements. For instance, the designer who prefers a long, slow climb will be more concerned with power output towards the middle and end of the power run, rather than with high initial torque, which may present unwanted difficulties in trimming out under full turns. The model designed for high climb with a short power run and a folding propeller will normally call for a motor with high average torque.







RUBBER ON TEST - PART 2
by Ron Warring and Bob Copland

From Model Aircraft, April 1954

As explained in the previous article, torque figures obtained on test were read in nominal scale units. We have no direct or accurate method of employing actual torque figures as a basis for model design calculations, but for simple performance analysis it is useful to be able to associate torque readings with actual speed of rotation of the propeller. The necessary conversion from scale torque to propeller r.p.m. can be obtained from Fig. 1.

To obtain the data for Fig. 1 a number of tests were run, taking simultaneous readings of torque and propeller r.p.m., using an electronic rev. counter to measure the latter. This imposes no mechanical load whatsoever on the system and thus in no way modifies the unwinding characteristics of the motor.

The curve of Fig. 1 applies only, of course, to the particular propeller used on test. However, it is a simple matter to arrive at a practical conversion factor for any other propeller by comparing the respective motor runs under the same conditions of test. To prepare the torque-r.p.m. data a standard 16 strand (Wakefield size) Dunlop 1/4 X 1/24 strip motor was used, wound to 550 turns. Motor run on the test propeller was exactly 60 seconds. To obtain a "conversion factor" for any other propeller size it is only necessary to time the propeller run on the same size of motor and same number of turns. This factor, applied to r.p.s. readings obtained from Fig.1 should then give a close approximation to r.p.s. for the new propeller.

For example, if another propeller showed a 50 second power run on the 16 strands test motor, appropriate r.p.s. figures would be 60/50 = 1.2 revs. per sec. figures as obtained from Fig. 1 ; and so on.

A detailed analysis was also made of the actual energy stored in the various sizes and brands of rubber motors used in the original tests. The total energy given out by a wound rubber motor is represented by the area enclosed under the torque curve. With all motors wound to an equivalent degree, computing the area under each typical curve would thus give an accurate indication of the "power potential" of each type of motor. The one with the greatest area would show itself as capable of delivering more power for the same weight of rubber, if such differences did exist.

This theoretical assumption, however, is not of direct practical application. Readings over the first part of any practical torque curve are unreliable, since the torque is dropping rapidly over the first five seconds or so and a fraction of a second's hesiitation in taking a reading may mean a considerable difference in the scale reading noted. By the ten second mark torque has settled down quite well and from then on readings can be taken with extreme accuracy.

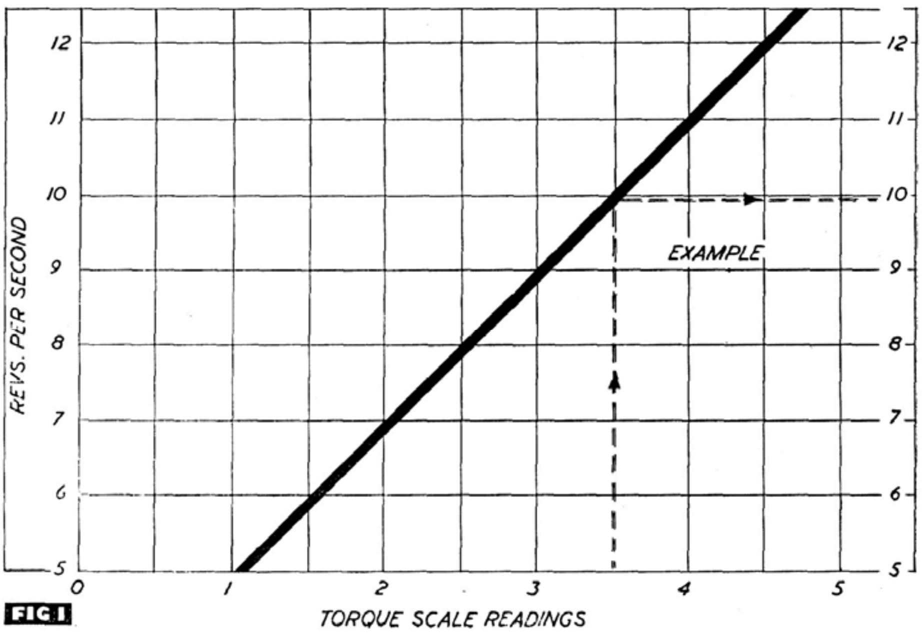


FIG I

Calibration curve showing torque scale readings in terms of revolutions per second on standard 18 in. diameter 30 in. pitch Wakefield propeller. Example: when the rubber motor is developing 3.5 (units) torque, corresponding propeller r.p.s. is just under 10, or 10 x 60 = 600 r.p.m. Curve may be used to give r.p.m. figures for other sizes of propeller, as explained in the text.

Method of analysing typical torque curve on the basis of "energy utilisation" or amount of useful power produced by a rubber motor. Area under curve is plotted from 10 second point on. Initial power output is calculated on a theoretical basis due to unreliability of readings over the first 10 seconds of the power run.

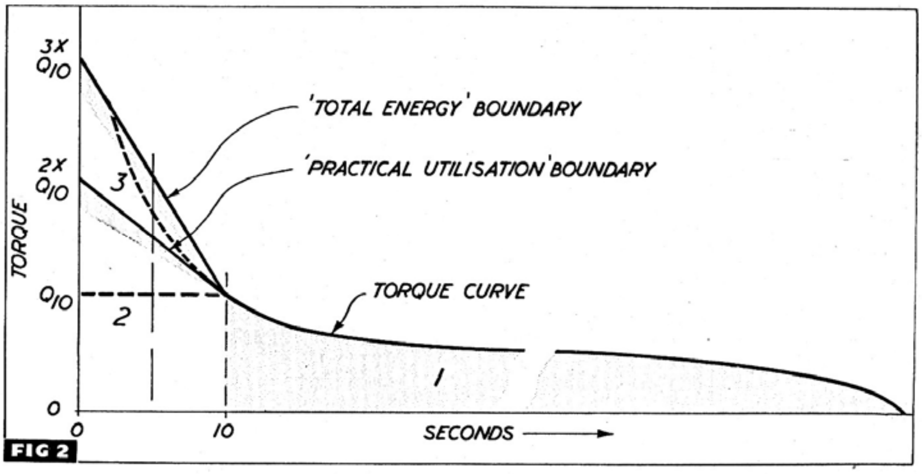


FIG 2

Hence as far as the existing test data go, plotting the area under the respective torque curves after the 10 second mark should afford a pretty fair comparison of power output. These data are, in fact, summarised in part I of the table.

If the resulting areas are taken as criteria of "rubber efficiency" it will be noticed that efficiency decreases as the cross section of the rubber is increased (for the same total weight). The reason for this is quite clear. Starting at the 10 second mark on the torque curve, the more powerful the motor the greater the proportion of total energy not included under the curve, because both torque is higher in this region and also 10 seconds represents a higher proportion of the total duration of the power run. To get a true comparison, therefore, it is necessary to re-construct the first 10 seconds of the power run on empirical lines.

A very fair comparison is given by assuming that the initial (0 seconds) torque is three times the torque at 10 seconds with a purely linear relationship between torque. at 0 seconds and 10 seconds. 1t is then a simple matter to add the area enclosed by this trapezoid shape to the area already found under the torque curve from 10 seconds onwards. This is done in part 3 of the table and, for convenience, highest values obtained were designated 100 percent and all other values then converted to similar percentages.

Theoretically, wound to the same degree (i.e. 80 percent nominal maximum turns with the test motors), figures for the same rubber strip should be identical, whatever the number of strands. This is not achieved in practice, if only because the "80 percent" turns figure is a nominal one. Also there may be some difference in internal losses with the motor arranged into different numbers of strands.

Allowing for these factors, it is interesting to note that three of the four rubbers tested have almost identical characteristics, whilst the fourth is somewhat down. There is a possibility that this particular rubber was more fatigued than the other test speciimens since it did, in fact, have a much shorter period of rest between running-in and testing than the others and it was also tested at turns figures subsequently found to be nearer 73 per cent. maximum than 80 per cent.

Part 2 of the table is probably of more direct practical interest for this is based on the assumption that it is never possible fully to utilise the "peak" power of a rubber motor. If the model is trimmed out to absorb full power, almost certainly the trim will be less efficient than it could be over the remainder of the power run, and vice versa. Bearing this in mind a good criterion of "practical utilisation" is to assume that a nominal peak power of twice the 10 second torque figure represents the maximum which can be accommodated without having to use the latter part of the power run less efficiently than it could be (without some form of mechanical trim-changing device). Hence the first (calculated) part of the area under the "working" torque curve has a peak (at 0 seconds) of twice the torque at 10

Conclusions which may be drawn from these data are that there is not a great deal of difference between three of the four sizes of strip, at least. Any differences are probably within the range of experimental error to be expected with such tests and methods of analysis. It would appear, however, that for a high-powered motor (e.g. 16 strands of 1/4 strip equivalent), Dunlop 1/4 strip appears slightly superior to Pirelli, whereas for low power motors (12 strand 1/4 strip equivalent), Pirelli has the advantage. Dunlop 3/16 in. strip, on the other hand, appears to follow Pirelli characteristics, showing a slightly greater efficiency with smaller cross section motors. It does, in fact, appear a very good rubber in this respect.

The Pirelli 3/16 tests are probably lower than the actual potential for this rubber, for reasons previously stated. Actually the reason for the later "make-up" of these test motors was that a specimen of sub-standard strip was submitted in error and a sample of the new batch had to be obtained after first tests had indicated the sub-standard nature of the original specimen. A number of different skeins from the new production batch all checked as essentially similar in texture and general performance to the standard 1/4 strip, with the possibility of using it for "intermediate" motor sizes to considerable advantage due to its cross sectional area being lower than "standard" '3/16 X 1/24 in.

RUBBER "UTILISATION" DATA
ALL FIGURES EXPRESSED AS A PERCENTAGE OF "FULL POWER" OF ¼ STRIP

Test	Rubber	Number of Strands				
		12	14	16	18	20
1	DUNLOP ¼ x 24 ...	50	45	44	—	—
	DUNLOP 3/16 x 24 ...	—	—	57	50	45
	PIRELLI ¼ x 24 ...	54	48	45	—	—
	PIRELLI 3/16 x 24 ...	—	—	50*	45*	40*
2	DUNLOP ¼ x 24 ...	78	75	90	—	—
	DUNLOP 3/16 x 24 ...	—	—	88	80	80
	PIRELLI ¼ x 24 ...	83	80	87	—	—
	PIRELLI 3/16 x 24 ...	—	—	72*	72*	71*
3	DUNLOP ¼ x 24 ...	87	87	100	—	—
	DUNLOP 3/16 x 24 ...	—	—	100	88	94
	PIRELLI ¼ x 24 ...	91	90	100	—	—
	PIRELLI 3/16 x 24 ...	—	—	80*	80*	80*

* These figures are lower than the true performance of this strip size.

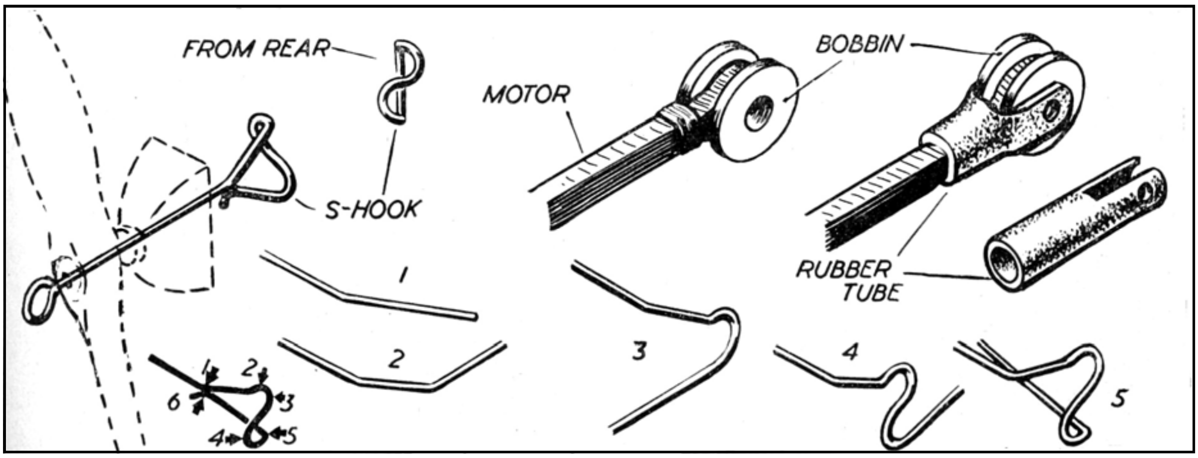
FITTINGS FOR RUBBER MOTORS

Circular and diamond shaped front hooks for rubber motors suffer from the defect that the wound motor often tries to "climb" round the wire, resulting in an uneven motor run, or even rubber bunching and jamming the shaft completely. S-hooks completely eliminate this trouble, provided they are bent the right way round, and are true as regards alignment with the shaft.

An S-hook is a self-aligning fitting. When wound, the motor tends to creep to the exact middle of the S and will remain there. Bend the S the wrong way round and the motor will work right off the ends of the S, showing just how positive motor "creep" is with this type of hook.

The S-hook is easy to bend, if you follow the six simple stages shown. The two half circles which form the actual S shape should be made with round-nosed pliers. After completing stage 5, make sure that the centre of the S is lined up accurately with the shaft.

For the rear rubber fitting, loop the strands over a bobbin and bind tightly up to the bobbin with a rubber band. This will give a convenient, anti-bunch fitting for the' back of the motor and one which is readily secured by the rear peg passing through the centre of the bobbin. This is a perfectly satisfactory arrangement for moderate length motors, but bunching troubles may still be experienced with really long motors. The cure here is to use a bobbin, as before, but slip over it a length of stiff rubber tube (e.g. rubber gas tubing) which has been slit and pierced so that it can be drawn over each side of the bobbin. The rear peg then anchors the rubber tubing as well as the bobbin and provides a stiff "lever" to prevent the motor doubling back on itself into a bunch.



RUBBER MOTORS

from June and July 1966 Aeromodeller

The type of rubber used for model aircraft is specially formulated so as to have a consistent performance and good 'stretchability' (an elongation of about 800 per cent). It is normally made in 'strip' or rectangular sections, because experience has shown that this is more durable than 'square' sections. Standard British (and American) sizes are 1/4in., 3/16in. and 1/8in. wide in either 1/24th or 1/30th inch thick. Thicknesses are often designated by number only, e.g. 1/4 x 24 instead of 1/4in. x 1/24th.

Dimensions are nominal. That is to say the actual dimensions of different makes of the same specified sizes of strip can vary somewhat. Dimensions, and performance, can also vary somewhat from different batches of the same make and in some cases from one end to the other of the same batch of rubber. This is due to the fact that the rubber is formed initially as a sheet, wrapped around a drum for vulcanising and then subsequently cut into strip widths, and variations can occur in processing.

The effect of such variations can be of critical importance for contest flying. The merits of each batch or hank of rubber need to be established by practical tests, in order to be sure that it is suitable; and the best performance usually comes from unused rubber which has been aged. That is to say, given two batches of rubber from the same manufacturer and to an identical specification, the one which is perhaps two or three years old will normally have a superior performance to brand new rubber. Sorting out the best rubber for contest flying, therefore, is a somewhat tedious business of continual trial and error.

For sports flying it is generally unnecessary to go to such troubles. Once a satisfactory motor size has been found then replacement motors of the same size in the same make should be satisfactory. Rubber motor weights and nominal maximum turns are also based on a 'standard' rubber representing typical mean average characteristics, and the aeromodeller can use these with confidence when he is not striving to extract the utmost performance from a rubber motor.

Typical strip rubber weights are shown in Table XX. These apply to dry rubber, as bought. When lubricated the weight of the made-up motor will be increased by about 5 per cent. As a general rule-and again only for sport flying-the rubber motor weight should be between 1/4 and 1/3 of the total weight of the model to get a good performance. That is, if the complete airframe, less rubber motor, weighs 4 ounces the rubber motor weight needs to be between 1¼ and 2 ounces, depending to a large extent on the size of the propeller. The larger the propeller diameter and/or its pitch the more rubber weight you can use, and the better the performance should be in consequence. You can use Table XXI for working out the actual length of rubber strip you require for making up motors of different weight.

TABLE XX
TYPICAL WEIGHT OF RUBBER STRIP (UNLUBRICATED)

SIZE*	OUNCES PER			LENGTH PER
	12 yds.	1 yd.	1 ft.	1 lb weight (feet)
1/4 x 24	2½	5/24	.0695	231
1/4 x 30	2	1/6	.0556	288
3/16 x 24	1⅞	5/32	.0520	306
3/16 x 30	1½	1/8	.0418	384
1/8 x 24	1¼	5/48	.0347	462
1/8 x 30	1	1/12	.0278	576

* variable with different makes.

TABLE XXI
RUBBER LENGTHS IN FEET FOR GIVEN WEIGHT

Motor Weight Ounces	RUBBER SIZE					
	1/4 x 24	1/4 x 30	3/16 x 24	3/16 x 30	1/8 x 24	1/8 x 30
1	15	18	19	24	30	36
1¼	18	23	29	30	37	45
1½	22	27	29	36	44	54
1¾	25	32	33	42	51	63
2	29	36	38	48	58	72
2¼	32	41	43	54	64	81
2½	36	45	48	60	72	90
2¾	39	50	54	66	79	99
3	44	54	57	72	88	108
3¼	48	59	62	78	96	117
3½	51	63	67	84	102	126
3¾	54	67	72	90	108	135
4	58	72	77	96	116	144

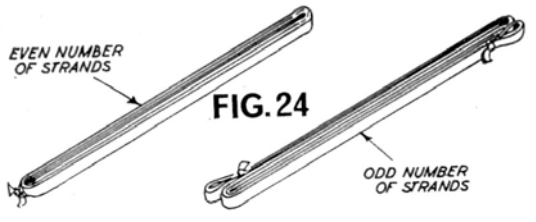


FIG. 24

It is normally most convenient to make up a motor into an even number of strands, when a single knot can be used to join the ends - Fig. 24. An odd number of strands would need a loop tying at each end, and knots can be a weak point in rubber motors. It is also important that knots should be tied before lubricating the rubber. A reef knot like that shown in Fig.

25 will then hold, provided it is drawn really tight. To avoid the possibility of tearing the rubber when drawing the knot tight wet the strip first e.g. by licking it.

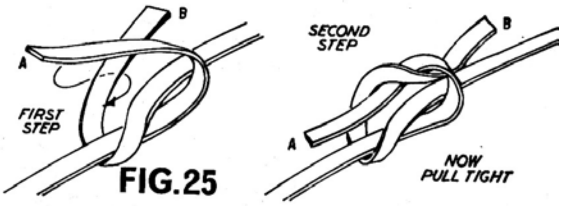


FIG.25

Knots made in lubricated rubber will always force themselves undone again, unless bound in place. The best form of binding is strong wool, knotted and re-knotted around the original tied ends whilst held stretched to maintain a tight original knot. Again a simple reef knot is satisfactory for the original knot, and this is the sort of repair job which can be carried out on a broken strand.

Lubricating the rubber is most important-and it is even more important to use only the right sort of lubricant. There are only two types, a mixture known as 'rubber lubricant' and made up from soft soap and glycerine; and pure (medicinal quality) castor oil. The former is a little more 'slippery', but pure castor oil is a perfectly adequate lubricant and saves the necessity of having to make up, or buy, a soap-glycerine mixture see Table XXII. Which you use is purely a matter of personal preference.
A made-up motor of optimum weight and with a

TABLE XXII
RUBBER LUBRICANT FORMULA

INGREDIENT	AMOUNT	MIXING
Pure soft soap (unscented)	4 ounces	Bring to the boil slowly in a clean pan, stirring all the time. Then allow to cool.
Glycerine	4 Tablespoons	
Water	½ pint	

suitable number of strands to match the propeller being used will inevitably be longer than the distance between the rear anchorage and the propeller shaft (unless the fuselage length has been specially designed to accommodate it). In its unwound state, therefore, such a motor will fall unevenly onto the bottom of the fuselage and upset the glide trim. This can only be avoided by providing some method of 'tensioning' the motor so that it remains taut when unwound-which really means stopping the motor unwinding completely. This can be done mechanically, e.g. with a tensioning spring and stop on the propeller shaft as in Fig. 26, but is much more simply achieved by pre-tensioning or 'cording' the motor itself.

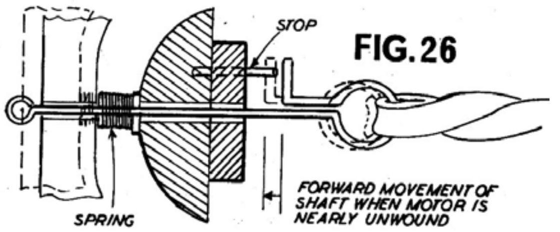


FIG.26

Steps in 'cording' a motor are shown in Fig. 27. Initially the motor is made up to twice the length required and one half the number of strands (this also means that the number of strands should be divisible by four to enable the ends to be joined by a single knot). The most convenient way to lay the motor out is in two 'legs" e.g. AC & BC-with a small marker--e.g., a piece of plastic knitting needle-bound to the centre of the motor with a rubber band. About 10 to 15 per cent of the nominal maximum turns of the motor are then wound on in the same direction as you would normally wind the motor. The two ends are then brought together, the middle indicated by the marker slipped over the winder hook and the doubled over motor allowed to unwind. This will cause the two skeins on the motor to wind up into a rope or 'corded' form with a considerable shortening of its original length. It then only remains to bind both ends of the motor with a rubber band to retain it in a corded state ready for use.

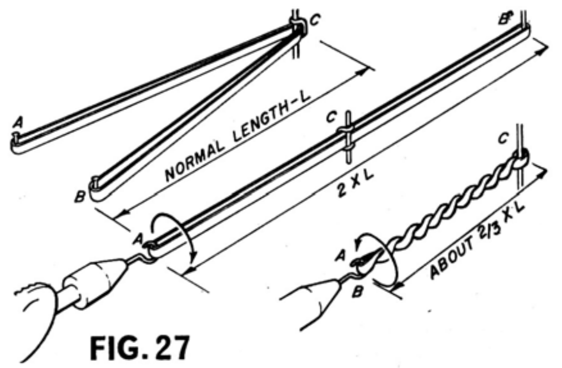


FIG. 27

Cording the motor in this fashion reduces the maximum turns by about half the number of 'cording' turns applied initially. The 'cording' turns may need to be adjusted on a trial and error basis--e.g. unwinding and re-cording-to achieve the desired tension. It may also be necessary to re-cord the motor, with slightly more 'cording' turns, after the motor has been broken in.

'Breaking in' is something that is very necessary with new rubber as, initially, it will not take anything like maximum turns without braking. Thus a new motor needs winding to about half maximum turns and then allowing to unwind; repeating winding and unwinding at about 60, 70 and 80 per cent maximum turns. The motor will then be reasonably 'broken in' and can be wound to approaching maximum turns from then on. During the process of breaking in it will also have stretched about 10 per cent in length, taking up what is known as the 'permanent set'.

For sports flying, motors should never be wound to more than 80 to 85 per cent maximum turns, when a consistent performance should be obtained over a reasonably long period. For contest work, however, it may be necessary to approach maximum turns on each winding. In such cases the 'maximum turns' figure (Table XXIII) can be taken only as a rough guide. The actual breaking turns can only be established by testing a specimen motor of that size (and rubber type) to destruction.

TABLE XXIII
NOMINAL MAXIMUM TURNS *PER INCH MOTOR LENGTH. (LUBRICATED RUBBER)

Number of Strands	RUBBER SIZE				
	1/4 x 24	1/4 x 30	3/16 x 24	3/16 x 30	1/8x30
2	60	63	66	82	90
4	46	48	49	51	63
6	36	39	41	44	51
8	30	33	35	37	44
10	26	30	31	33	39
12	24	28	29	31	36
14	22	26	27	29	33
16	20	25	26	28	31
18	—	24	24	27	30
20	—	—	23	36	29
22	—	—	21	25	28
24	—	—	—	24	26

* Typical mean performance with approx. 5% safety margin.

There is also the point that when a motor is wound to near maximum turns it will suffer a marked loss in performance after only a few windings. Some contest flyers may even change a rubber motor for each flight, although good rubber should stand up to at least three 'maximum turn' windings without loss of performance. It will not be suitable as a 'contest' motor afterwards, however.

Winding itself demands a special technique. Besides being quicker it is also a more efficient way of winding to use a winder, the usual type being a hand drill with a hook inserted in the chuck. The hook should be so shaped that it cannot pull out of the chuck, in addition to the chuck being tightened as hard as possible. Another useful tip is that the diameter of the winding hook should be of an easy shape to disengage from the propeller shaft and the propeller shaft loop of small diameter very little larger in size than the wire diameter of the winder hook. Fig. 28. This will stop the propeller loop trying to climb around the winder hook when winding.

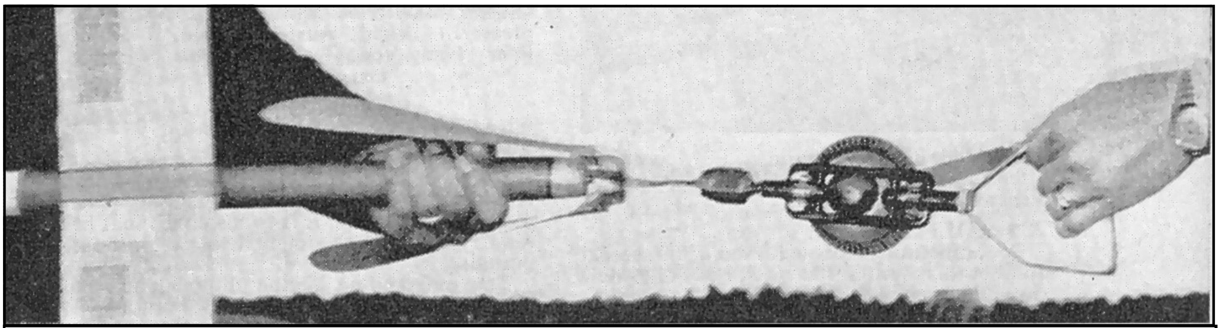
A rubber motor is always stressed less if stretch wound -and for putting on about 70 per cent maximum turns or more, stretch winding is essential. The technique is quite simple. After engaging the winder move backwards to stretch the motor to about three times its normal length. About one half to two thirds turns can be applied in this position, advancing towards the model as the remaining turns are applied. Judge the rate at which you take off the stretch so that you have advanced right up to the nose of the fuselage as the last turns are applied.

The initial 'stretch' is a little easier, and there is less strain on the rear anchorage, if turns are applied when moving out to the stretch position. This is particularly true if more than the '3 times' stretch is attempted. Some modellers use a 5 or even 6 times stretch when winding as they feel they can get more turns on this way. This is only for contest flying, and not always necessary then. It is largely a matter of individual technique, and the amount of stretch you feel happiest with.

A major problem with long motors is 'bunching'. There is also the ever-present problem with all rubber motors of the ends trying to climb around any conventional hook shape to which they are attached. The real answer is to avoid hook shapes as anchorages, and it was for this purpose the bobbin was devised.

Basically, a bobbin is simply a spool (preferably in plastic) over which each end of the motor is looped and the motor then bound close up to the bobbin with a rubber band - Fig. 29. The rear end of the motor is then anchored by a dowel through the centre of the bobbin. At the front end the propeller shaft has to be bent into a suitable shape to retain the bobbin. This shape is important for the bends must fit the bobbin snugly and accurately. If the bend is too wide, for example, the bobbin may be able to climb around the side of the hook. This possibility is aggravated by the fact that the centre hole of the bobbin is invariably much larger than the shaft wire diameter. It may pay, therefore, to plug the hole of the front bobbin to fit the shaft snugly, e.g. with a short length of split Rawlplug.

Bobbins are an ideal rear anchorage fitting; but with small motors they can be omitted and the dowel simply passed through the rubber loops. They are also a good anti-bunch fitting at the propeller end, but not always desirable. It is sometimes desirable, or even necessary, to use a hook.

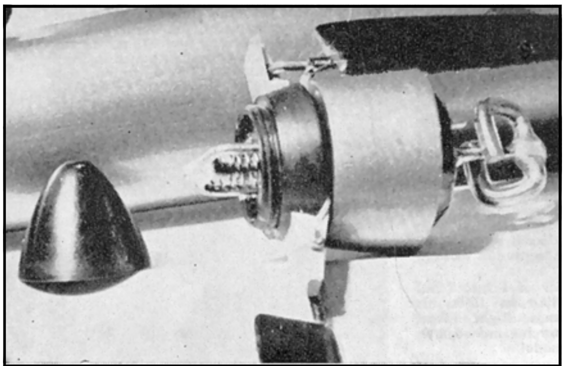


The traditional hand drill is an indispensible tool for winding rubber motors. Here, Lennart Flodstrom is about to stretch wind his Wakefield motor prior to coming 4th in the ‘65 World Champs.

No bent wire hook shape-circular, diamond and similar variations-is proof against bunching, with one exception. This is the 'S' hook, shown in Fig. 30. This is difficult to bend neatly and accurately, especially in 16 swg wire, but it is positively bunch proof provided it is bent the right way. The motor will then automatically align itself centrally with the hook under its own twisting action. If the 'S' hook is bent the wrong way the rubber motor will simply climb off the ends of the hook almost as soon as you start winding.

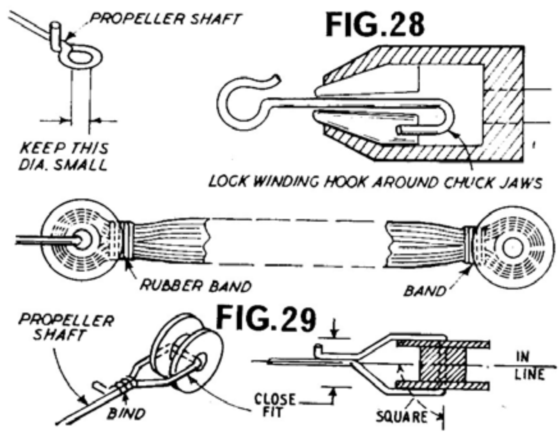
Where wire hooks are used in contact with rubber they should always be covered with sleeving. Bicycle valve rubber tubing used to be the standard 'sleeving' material, slid onto the hook. Plastic fuel tubing of suitable small diameter is even better and more durable. It may, however, need to be warmed to soften before it can be slid over a small 'S' hook.

Finally, whatever type of wire hook is used to anchor a rubber motor, make sure that this cannot straighten out under the pull of the rubber when wound, or during winding. The best method of preventing this is to bind the 'open' end of the propeller shaft fitting or hook with fuse wire, as shown in Figs. 29 and 30. This is more reliable than binding with a rubber band, as sometimes recommended, and easier to do.



Detail of Frenchman Jacques Valery’s conversion of plastic spinner for power models on a Wakefield design, also showing his non-bunch hook with plastic tubing covering. Prop hub is fabricated from wire.

This does not apply at the rear end of the motor since the anchorage here is usually a dowel pushed through the fuselage sides-but do use a strong enough material for the dowel, preferably really tough bamboo rather than an ordinary hardwood dowel.



Proper fixings - bobbins or 'S' hooks, prevent bunching at the ends of the motor, but bunching can still occur in the middle and upset trim, especially with long motors. This can be caused by poor winding technique putting on too many turns when stretch winding and then having to come in too rapidly. Bunching can also develop in a long motor when it is unwinding, and again can upset trim. This type of bunching will eventually clear itself as the motor continues to unwind, but the flight performance may be spoilt as a consequence. If a really bad bunch develops in a small section fuselage the rubber may become so jammed in the fuselage that it just cannot clear itself. This sort of fault is only likely to be produced by poor winding technique. The usual cause is over stretching and prolonging the 'stretch' too long; but it can also occur attempting near maximum turns without stretching enough.

Care of a made-up rubber motor is fairly logical and straightforward. Keep it clean and well lubricated (but not excessively lubricated). If it is dropped on the ground it needs washing, drying and re-lubricating before it is used again, as it will almost certainly have picked up grit. Keep all rubber out of direct sunlight or excessive heat as this will cause deterioration. Rubber, and made-up motors, are best stored in a cool, dark place.

Contrary to popular belief, made-up rubber motors do not want the lubricant washing off and storing 'dry' when not in use. Just keep them as they are in a suitable container. You can even leave them 'corded' without harm, although if they are to stand idle for more than two or three weeks it is advisable to uncord them first and re-cord again when you need them. If not, the strip may develop a sort of 'ripple' pressure pattern, although in fact this does not appear to have any harmful effect.

CARTRIDGE LOADING FOR RUBBER MOTORS

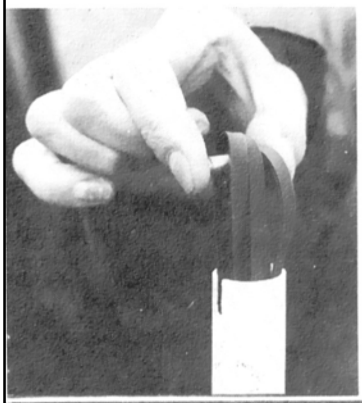
From April 1975 Aeromodeller

A number of today's Wakefield flyers use the cartridge-loading system for motors, which both protects the model from motor breakage during winding and also allows motors to be rapidly inserted into the fuselage. A complete description of the system first appeared in Free Flight News in November 1970; it was suggested by John Boxall who, in fact, had never flown a rubber model, and developed by John Mabey of the Croydon club.

Essentially suitable for models with motors that are tight between hooks - i.e. the majority of today's Wakefields - it consists of a length of tubing, often hard PVC electrical conduit, of a diameter that will slip through the nose former of the fuselage, and 2 or 3in. longer than the distance from the nose to the rear motor peg. Normal practice is to load several of these cartridges with motors, each secured into a slot at the rear of the tube by means of a hollow dural bobbin, on which shoulders are machined to prevent its slipping out sideways. The motor is stretched in the tube and a suitable pin passed through the T-bar to which it is attached at the front to hold the motor in place. In operation, the cartridge is slid into the fuselage until the hollow rear bobbin lines up with the motor peg holes in the fuselage sides; the rear motor peg (a length from the pointed end of a dural knitting needle) is then slid through the bobbin, holding it and the motor in place in the fuselage.

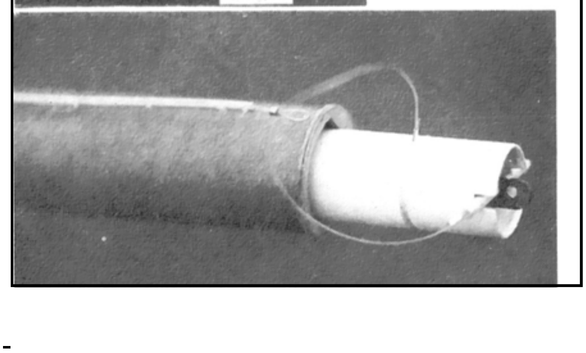
A normal tube winding extension to the drill is used, a few inches longer than the cartridge, to allow the latter to be slipped out completely clear of the fuselage and T -bar once the rubber is wound. To wind, the T-bar is connected to the extension and the front retaining pin removed from the cartridge, allowing the motor to be stretched out and wound. After winding, the cartridge, which has been protecting the fuselage from a burst motor, is slipped out and over the winding extension; a suitable steel pin is slid into the T -bar and rests against the nose former, held against motor torque by the helper, while the extension is unhooked and the prop. fitted. Once the Montreal stop is set, the helper's pin is removed and the noseblock fitted in place.

An advantage of the system was found by Ian Kaynes last year. With the motor fully wound, but still in its cartridge, he had a problem with his propeller two minutes before the end of a round. The answer was to transfer the fully-wound cartridge-enclosed motor to his spare model, attach the correct prop. and fly it.

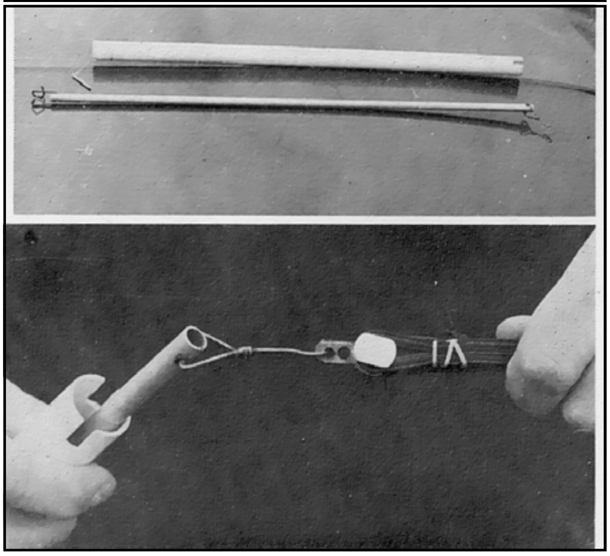


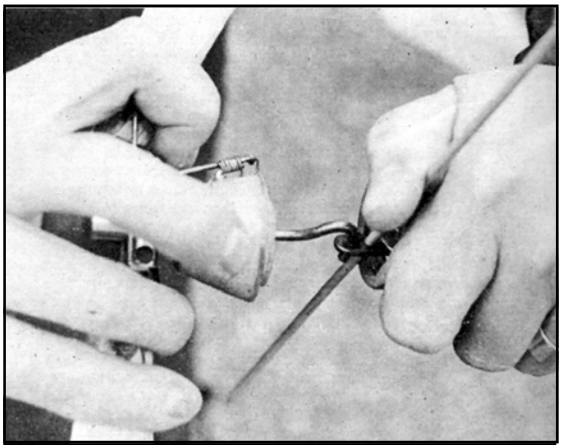
Left: Rear bobbin is slipped through the rear end of the motor once it is in the cartridge, and located in the slots.

Below: loaded cartridge is slipped into fuselage. Note retaining pin holding T-bar in place.



Below is the hard PVC electrical conduit, used for the 'cartridge' loading system described, together with the dural tube winding extension - note retaining pin tied to left end of cartridge to prevent loss, also wire fittinlS at each end of extension tube for winder and T.bar. At bottom, the cartridge is being loaded. The motor has been attached to a modified form of T .bar (it has end flanges), then the extension is hooked to T.bar. This is necessary as the cartridge is lonaer than the unstretched rubber. Note, too, the slots to retain the rear bobbin when cartridge is loaded.

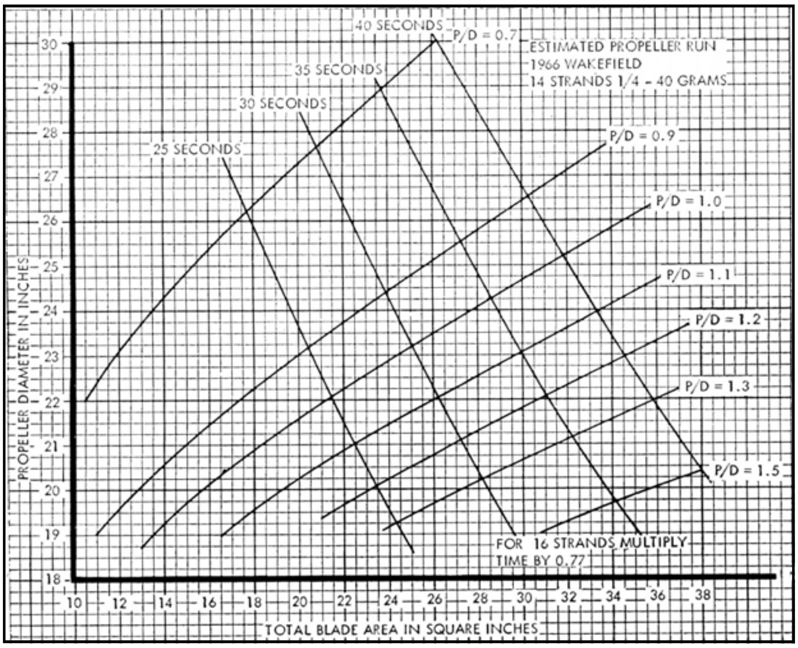




Winding completed, slide the cartridge out over the winding extension, then slide knitting needle through the T-bar (hold against nose former) while extension is removed. While helper still holds the torque of the motor via the knitting needle, replace the propeller hook on the second hole of the T-bar.

With the model's motor peg passing through the rear bobbin of the loaded cartridge, use the cartridge itself as a winding tube when applying the turns. The helper takes the pull on the exposed front end of the cartridge as the motor is fully extended. Martin Dilly demonstrates the hold as Paul Masterman winds.

MOTOR RUN RECKONER FOR 40 GRAM MOTORS
by J. Grant



The graph presents a cross plot of propeller diameter, blade area and pitch diameter ratios against motor run for 14 strands of 6 x 1 weighing 40 grams. It is reproduced by permission of "Internationalist', Canada. Note that changes in blade area will vary the times only slightly. For example, assuming a 22 in. diameter, P/D of 1.0 and a blade area 0121.5 sq. ins. an estimated run 0125 seconds Is indicated. Increasing the area to 30 sq. Ins. will only alter the run time of

$$25 \times 3\sqrt{\frac{30}{21.5}} = 25 \times 1.12 = 28 \text{ seconds}$$

Winding to the absolute maximum could also Increase the run up to say, 10%. Although the plot Is theoretical, quite a number of propellers have been checked

TESTING COMMERCIAL RUBBER
The results of some interesting tests undertaken by R.J. North and other members of the Croydon & DMAC - reported by M. Dilly

From February 1961 Model Aircraft

When the Wakefield rules were changed for the 1958 competition, reducing the amount of rubber allowed from 80 grammes to 50 grammes, I (R. J. North) was not really interested. The fortunes of the Croydon & D.M.A.C. were at a low ebb, and it did not seem likely that anyone would bother to build a model for the new rules. Further, to many of us, it seemed that the good old days of Wakefield models had gone when the limited rubber rule was first introduced, and this new change was the bitter end. The performance of the models would be so low that they would be uninteresting to fly.

However, I did have an 80 gramme Wakefield which was pretty useless, and one evening, when I had nothing better to do, I cut an inch off the propeller blades, 6 in. out of the fuselage, discarded the pylon and installed a 1.75 oz. motor. It flew from the start, and what is more, it had a much better performance than in its original form with 2.8 oz. of rubber. This was surprising and I decided to persevere with these new rules. Altogether I made about 50 flights, fully wound, with this model before the 1958 Trials and none was under 150 sec., many being dethermalised at around 180 sec. Having seen no other new rule models in this class at Chobham, this seemed to be good enough, especially as the model was extremely stable and reliable.

There was, however, one snag. In test flying, all the original batch of rubber had been used up, and I had to find some more. In principle this was easy, go to a shop and buy some. Unfortunately that season (early 1958) I had already found that there was no rubber of good quality available, either Dunlop or Pirelli. A search started for old stock and eventually Ron Ward turned up with some anonymous 1/4in. X 1/30 in. strip. Flight tests were made and the performance seemed reasonable, if not quite what it was with the original Dunlop.

So far, all test flying had been done at Epsom or Chobham with the usual uncertainties which prevail at these two sites. By way of a digression it might be mentioned, for those who are not aware of this situation, that the performance of a model can be very different on a flat airfield from what it seems to be on a hilly site. Thus it is rather difficult to assess the likely performance of a model on an airfield, by test flying at the grounds available to the London area. Further, the terrain at Chobham is so rough that five or six full length flights are all that anyone wants to do in one day. This factor, and the relatively high chances of damage on landing, tends to reduce the amount of test flying which can be done. However, I went to the trials with some hopes.

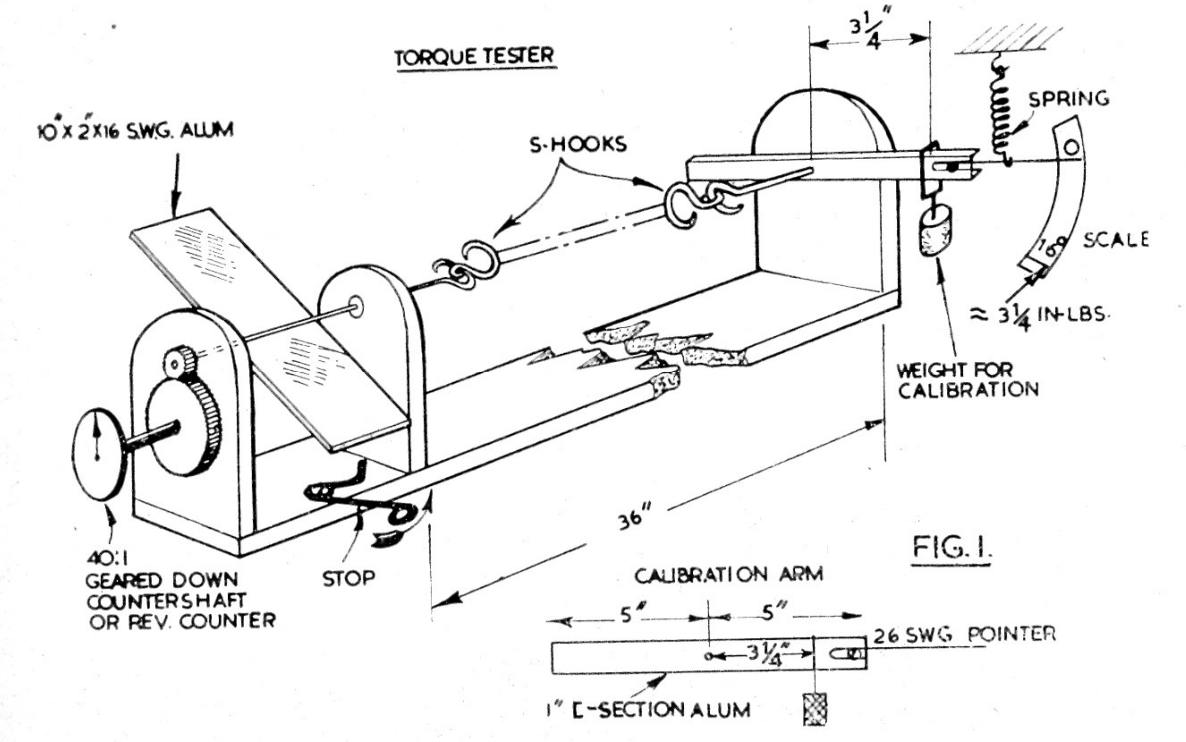


FIG. 1.

You may recall that Ron Draper had the model of the year, John Palmer's model was performing with 1.75 oz. of rubber as it had in previous years with 2.8 oz., and John O'Donnell had a wonderful climb; Eric Barnacle and Ray Monks also had notable models. John Palmer got into the team, and the Croydon contingent went home not too unhappy as a club. For myself, I had two troubles: (a) the rubber was obviously not as good as the Dunlop I had been using, and (b) even allowing for this, the model did not compare in performance with some of the others.

The answer seemed to be to do a little research into both aspects but the rest of this article is concerned with the rubber question.

The usual method of testing rubber is to make test flights, but this process has several disadvantages:

(a) The results are subject to far too many variables.

(b) In order to eliminate the effect of these variables, many tests have to be made to obtain an average. This takes a long time.

(c) The results may only apply to one model. To confirm that they do not. requires further prolonged testing.

(d) Repeated testing with a changeable material like rubber is of questionable value.

(e) Suitable test conditions occur only occasionally.

On the other hand, if the experimental conditions can be controlled, the results can be relied on and repeated if necessary. Some years of experimental work have shown that results are of no value unless they can be demonstrated at will. If this is not so, no one believes the answers, soon not cven the experimenter himself!

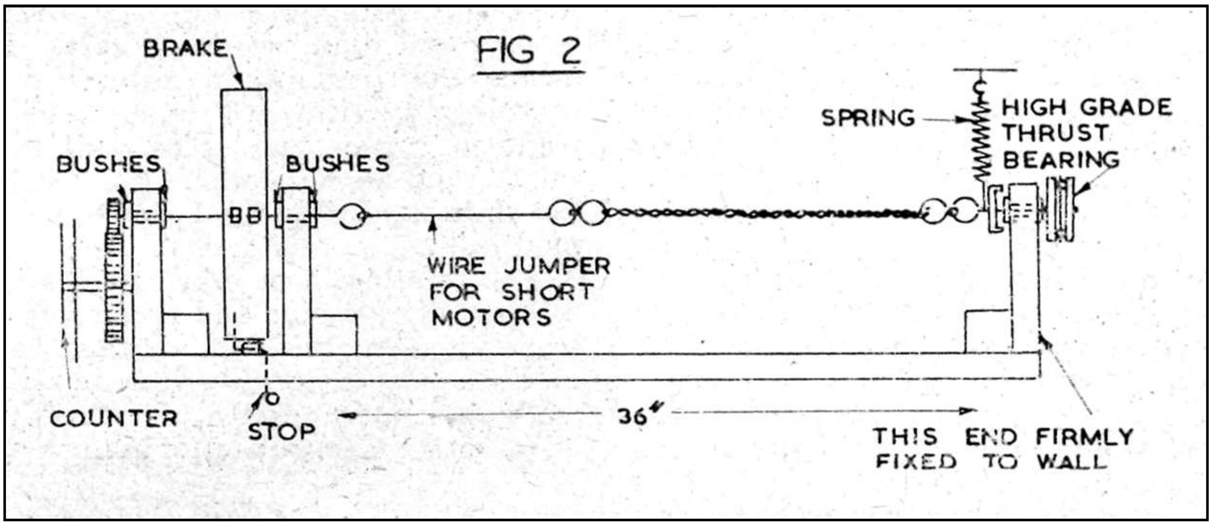
RUBBER TESTING

As a preliminary exercise we (R.J. North and P. Scarbrow) had been using for some months a small torque indicator for use when winding motors. This soon proved what was confirmed later:

(a) That the torque of the motor whilst it is being wound can be misleading as far as the unwinding torque is concerned.

(b) That the maximum torque of the wound motor (which is the same as the maximum torque of the unwinding motor) is not the whole story.

The torque of the unwinding motor is what drives the propeller and is all that matters; the torque required to wind the motor is greater and, within limits, it does not matter how much greater. A certain weight of rubber is allowed (or can be carried), and what counts is how much energy it can deliver during unwinding.

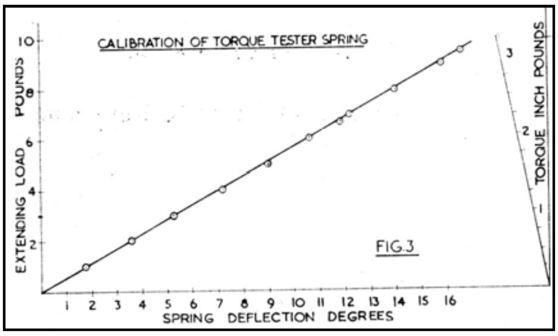


The torque indicator consisted of a thrust-bearing from a war surplus bombsight computer, a spring wound from piano wire, a paddle blade to act as a load (i.e. a propeller), and a gearbox to reduce the speed of the driven shaft so that the revolutions could be counted easily, either visually or by a revolution counter.

The first machine actually drew the torque curve in ink on a paper-covered rotating drum driven by pulleys. However, I had more trouble with the pulley drive than anything else and as I needed the answers quickly, the device was simplified by omitting the graph plotting facility. It is, however, a worthwhile convenience if it is done properly, and I am sure that a mechanism made from Meccano parts would be fine. It seems to be a sign of the times that bombsight parts were easier to come by than Meccano.

The general arrangement of the machine is shown in Figs. 1 and 2 and the only part that is critical is the thrust bearing, which should be as frictionless as possible. The bearings of the other rotating parts do not matter in this respect, as the energy of the rubber can go in bearing friction, as well as spinning the paddle blade. The torque measured at the other end of the motor and the number of revolutions will be the same, but the time taken to unwind will be a little longer if there is some friction.

The work done by the motor is calculated by plotting the torque against the revolutions, and measuring the area under the curve (for explanation see any elementary maths textbook on analysis). It is not necessary to calibrate the torque meter in oz.-in. or lb.-ft. if only comparative tests are proposed. However, it is better to do so in order to be able to exchange results with other workers. Calibration is arranged by hanging weights on the pointer arm to extend the spring in the same manner as the rubber torque. It is worthwhile doing this before you start serious testing in order to confirm that the extension of the spring you are using is proportional to the load (Fig. 3).



It is not, of course, necessary actually to measure the area under the graph if the intention is merely to compare motors, since the relative merits of two motors can be seen by inspection of the graphs. Alternatively, a quick check can be made by adding all the torque readings together, but for this to be valid, the intervals must be equal.

PREPARATION OF THE MOTORS

If you weigh out 1.70 oz. of rubber (as I do), then make up a motor of so many strands and measure its length, you will generally find that the resulting motors will be of varying lengths. The question then arises: how to test motors of different lengths and therefore different cross-sections or densities? The method I have used is to make up the motors to initial lengths of about 22-23 in. and let the number of strands come out 10, 12, 14, or 16.

Someone will now object that each of these motors will take a different number of turns before breaking. This is no doubt so, but some sort of standardisation has to be introduced to simplify the problem, so that our minds can concentrate on the main aspects. So, whatever the motors might take in the way of turns, they are pre-wound to 240, 320 and 400 turns, the last wind-up on 400 turns being used as the test run.

The next wind-up can be a contest flight with 420 to 440 turns on; I have used this procedure on well over 50 motors and found it acceptable. I am aware that running-in rubber motors is a bit of a fetish with some, and if they want to run-in motors as well as test them, they are welcome. For me life is too short and anyway I detest winding motors.

The motors are lubricated with a mixture of glycerine and green soft soap. There is a practical advantage in this mixture over castor oil-it comes off the wallpaper more easily after you have been using the torque tester in the lounge!

Now for some practical results, but one word-if you do not like them and think I am wrong, do not buttonhole and tell me you think so. Build a machine, do some tests, and prove it. Then you will believe my results, and I will be able to believe yours.

HOW DO THE RESULTS REPEAT?
One of the first precautions was to check that tests on a particular motor would repeat. This was done by testing a motor one day, using only about half turns so that the rubber was not worn out, and repeating the test the next day, and so on.

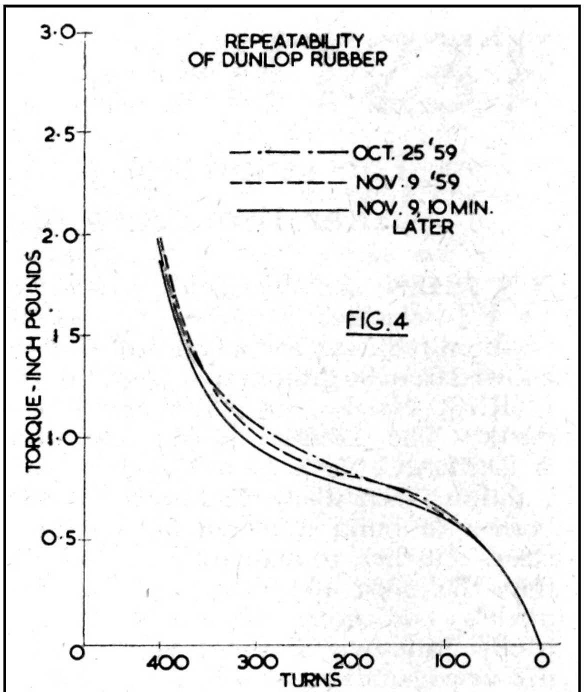


FIG.4

Fig. 4 shows three plots of the same Dunlop Wakefield motor tested on October 25th and November 9th, 1959. The two tests on November 9th were done within 10 min. of each other to show the effect of not allowing the rubber to relax between tests, or between flights.

DIFFERENCES BETWEEN GOOD AND BAD MOTORS
Fig. 5 shows the results of tests on: (a) a very good motor, one of the best two or three I have come across (Dunlop, bought in winter, 1958). (b) An average motor, actually one of those used by Denis Partridge to win the Croydon all-corners Wakefield contest at Chobham, winter, 1959-60. This particular motor was chosen because it is typical of recent Dunlop commercial production. (c and d) Two very poor motors, one Dunlop bought in early 1958, one Pirelli bought in mid-1958. Note the remarkable similarity in the curves; there was no catch in this-they were different rubbers of different colours.

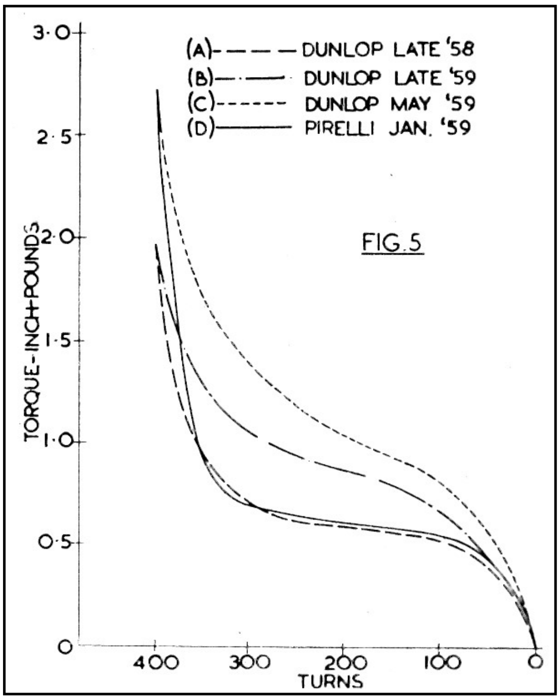


FIG.5

If you consider the area under the curves as proportional to the energy available, in each case the differences in performance to be expected are quite startling. This, of course, merely confirms what most Wakefield flyers already know, but it is nice to be able to demonstrate it, indoors, in front of the fire. Note also that the maximum torque levels recorded do not indicate whether the motor is any good. In other words the motor can feel very tight when you stop winding, and when you release the model it whirrs away for about 20 ft.; then the torque falls rapidly to the almost horizontal portion of the curve and the model levels out. You realise it is another of those debacles and wonder why you do not stick to power, until you recall that rubber is at least quiet and clean.

HOW DO VARIOUS MAKES DIFFER ?
The graphs show that rubber from major suppliers varies a great deal. I have shown in Fig. 5 how two poor motors of different manufacture can be very similar in performance, and Fig. 6 shows how two fairly good examples, one Pirelli and one Dunlop, compare. You can see that they do, in fact, compare very well, and that there is no evidence so far that one type of rubber has a different torque curve from the other.

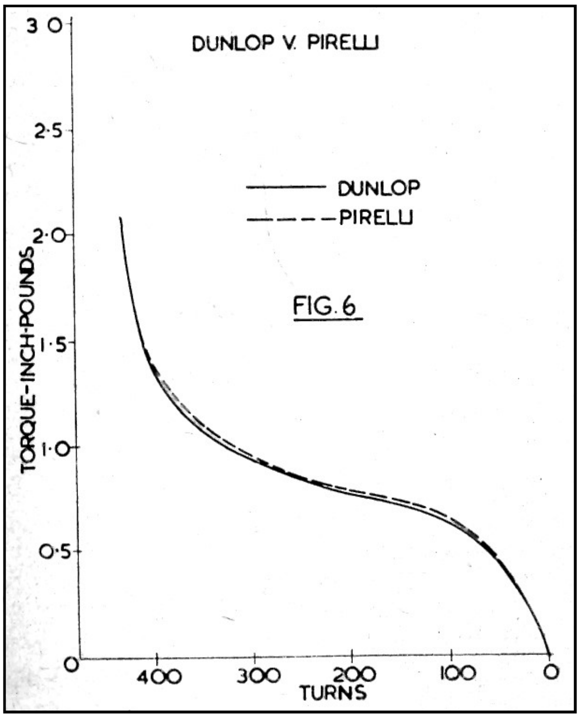


FIG. 6

You will note that I do not say that such differences have not existed in the past or will not exist in the future. All I know is that they cannot be demonstrated with samples available to me since 1958.

Like everything else, we know that rubber was better in the past. If we had any to test we could prove it; unfortunately most of the old rubber still left has been well used, and it is no longer in its prime. However, I did get a sample of unused, carefully stored, 1953 Pirelli from one of my friends who has "kicked the habit". Imagine my dismay when it turned out to be only so-so. What fearful doubts arose in my mind? Were the good old days as good as they seem in retrospect? Or could it have been that we used more of the stuff then and were satisfied with less in the way of performance? The curve for the 1953 Pirelli (first registered 1959) is rather lower than the middle curve in Fig. 5 (it has not been plotted in order to retain a simple presentation).

VARIATIONS IN DIFFERENT BATCHES
In 1959 when I made the Wakefield team, I went home and dug out some Dunlop bought at the same time as the two skeins used for the two Eliminators and two Trials. This was to be used in the Wakefield Contest but I was in for a bit of a disappointment. It was no good. So a search began for something better, and a large number of motors was made up and tested. This was the only way, because it had already been found that there was a considerable variation in the motors made from one skein (about 1 lb.). Therefore, testing one motor from the end of a skein told me nothing about what else there might be in it.

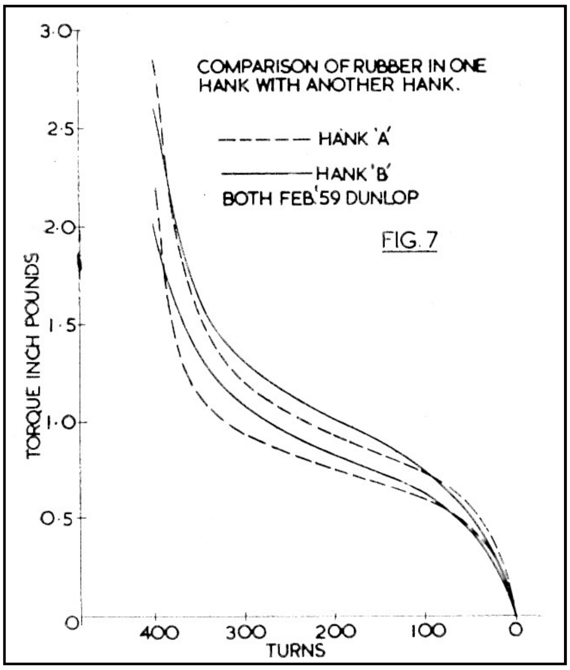
It took about three solid days to confirm that I had better stick with the motors I had already used, rather than try newer and less satisfactory material. This decision, undoubtedly the right one, was made on the basis of machine tests alone as by that time I had complete confidence in the information it gave. Even since the contest I have not come across any motors which compare with those I used then, except some which John O'Donnell bought from a shop in Manchester in February, 1959. It seems likely that these were from the same batch of production from Dunlop as my two motors.

When next you read some statement by an expert on these things-how, if we were more serious about this business of aeromodelling and selected our teams in a different way, we might do better in International Contests-you will, perhaps, recall that I tested over 50 motors in three days to select a few to use! I saw a previous Wakefield winner making up his motors the night before the event at Brienne-le-Chateau. You might also like to know that, after I had won the Trials, I was asked what rubber I was using. I told the enquirer Dunlop, and he remarked that the others in the team had used Pirelli. I gathered from his tone that I was in error in using Dunlop; at this I'm afraid I was a bit offhand.

The point I am making is that, over a period of years, I am sure that more commonsense development has gone into model aircraft in this country than anywhere else, including Russia and America. But none of this is enough in a contest-one needs luck, too and this element, on occasion, cancels out all else.

I do not know what has been done elsewhere in rubber testing, but this article contains the first set of data published anywhere in the world, giving actual figures and stating the rubber makes, on more than just a few motors.

As a result of the tests made before the 1959 Wakefield contest, Fig. 7 shows the spread of curves for eight motors made from each of two skeins of Dunlop rubber bought on the same day, 16 motors in all. You can see that there is considerable variation and some overlap.



SPECIAL BATCHES

Some tests have been made in collaboration with Dunlop but I have not been informed of the results of these tests. As far as I can tell, the product available in the shops is not any better than it has been at various times in the past. However, none tested recently is as bad as that sold in early 1958 and so there could have been some improvement in the consistency of the product. Only time will tell on this count.

ACKNOWLEDGMENTS

I should like to acknowledge the co-operation of many members of the Croydon & DMAC in this work. In particular Pete Scarbrow and Dennis Partridge for help with test flying, Ted Setterfield (of Heset Model Supplies) and Ron Ward for providing rubber samples, John Palmer for lending some of his known good motors and for assistance with tests in collaboration with Dunlop Rubber Co. Ltd. Thanks are also due to John O'Donnell for discussion, provision of motors for test purposes, and for a copy of his report on rubber testing.

RUBBER

From August 1979 Aeromodeller

With the recent availability of good rubber from several sources, more and more people seem to be building Wakefields and Coupe models, and may need some hints on the care and feeding of 'The Rich Man's Motive Power'. As supplied, rubber strip is lightly dusted with talc, as a means of avoiding sticking of adjacent strands in manufacture and storage of the hank. Talc, however, is not a good rubber lubricant and therefore should be thoroughly washed off once the correct weight of rubber has been cut off the hank.

When storing rubber, by the way, whether in a shop or at home, make sure that it is kept cool and away from the light; ultra-violet light, present in daylight, causes rapid deterioration of natural rubber, so it is only sensible to store both stock and made-up motors in light-tight containers. Rubber should not be stored wound tightly on a spool; if bought in a hank make sure the knots tying the ends neatly to the rest of the rubber are loose and not deforming the material.

Newcomers sometimes have difficulty in knotting a motor; several ways exist, but here are two that work. Start with washed and dried rubber in both cases. Method A: tie a single overhand knot very tight in each end of the rubber, and then lick the ends before tying them together in a reef or square knot. The saliva acts as a lubricant to enable you to slide the initial overhand knots tightly against the reef to act as a lock; it is worth trying a minute spot of cyano-acrylate on the knot to further inhibit slipping. Method B: originated, like some other good things in free-flight, by Jack North, this system uses a simple self-clamping jig to hold the ends of the rubber overlapped and tight while they are bound with wool or thick de-waxed carpet thread.

RUBBER MOTOR CALCULATIONS

How many turns can be safely wound on?

How long is a Wakefield motor made up from 'x' strands of standard strip?

From September 1966 Aeromodeller

The diagram overleaf actually comprises two separate nomograms, one occupying the whole space which gives solutions for maximum turns from any size of rubber strip, made up into a motor of any number of strands. The second nomogram is entirely self-contained and enclosed within the chain dotted 'box' This is used separately for finding the size of Wakefield motors to the new 40 grams maximum rubber weight.

Dealing with the main nomograms and the method of arriving at general solutions first.

On the extreme left hand scale are a number of black dots, corresponding to all the standard aero strip sizes (and also two of the square sections which are not normally used for rubber motors). Select the 'spot' corresponding to the size of rubber strip being used and connect with a straight line to the number of strands in the motor on the extreme right hand scale. .

Note the point where this line cuts the reference line (the centre line of the nomogram.) Connect this point with a straight line to the actual *length* of the motor on the inner left hand scale. Then simply read off the 'safe maximum' turns for that size of motor on the maximum turns scale.

Example: to find the 'safe maximum' turns for a 10 strand motor in 1/4 X 24th strip, 26 in. long.

Answer: 680 approx: (676 by close reading of the scale).

Note: the 'maximum turns' given in this manner is based on the performance of typical aero-quality strip in good condition, with the motor lubricated and properly broken in. Actual breaking turns will be .001 some 10 to 20 per cent higher, depending on the quality of the rubber. Note also that both the 'safe maximum' and anticipated 'breaking turns' of the motor will be reduced somewhat if the motor is corded to pretension. In this case the actual 'turns' figure to work to should be taken as the calculated number of turns less one half of the number of turns applied to the motor during 'cording'.

Aero strip sizes are nominal and the actual cross section of a particular sample may vary slightly from the 'nominal' size. In this case, if you want to be more accurate, you can enter the actual cross sectional area (which you will have to calculate) on the left hand scale, rather than work from the 'nominal size' spot.

To extend the application of the nomogram to actual test results, these test results are used to recalibrate the 'size' of strip on the extreme left hand scale. To do this the nomogram is worked backwards, involving the following stages.

(i) Test any suitable size of the same rubber to destruction and note the number of turns at which It breaks. To save rubber this can be done with just a two-strand motor, say 10 inches long. Make several tests and take the average of all the breaking turns figures found.

(ii) Enter the length of test motor(s) on the left hand inner scale and connect to the actual breaking turns, continuing the line to meet the reference line.

(iii) Draw a line from the number of strands of the test motor through this point extending across the nomogram to cut the extreme left hand scale.·

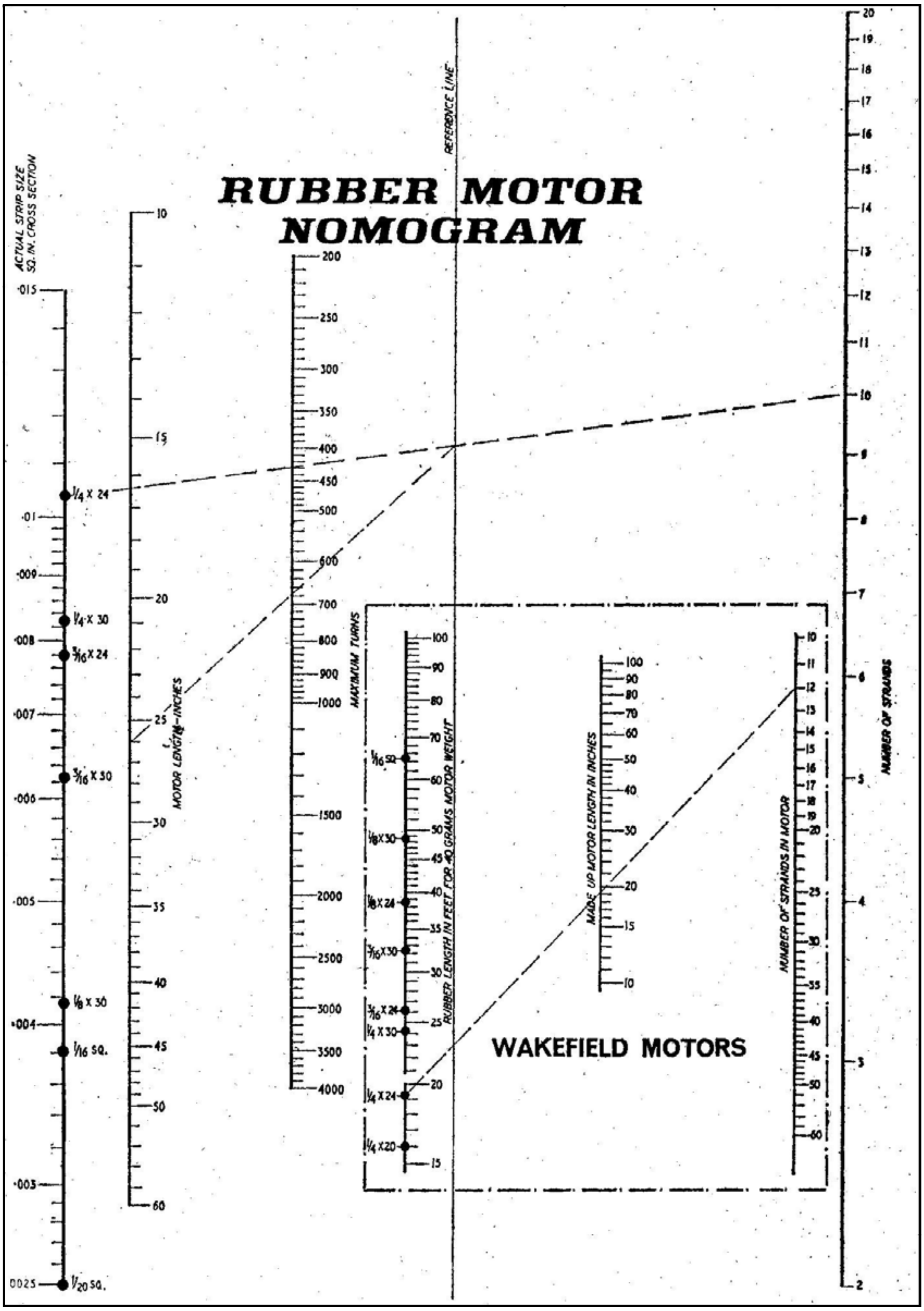
(iv) Mark this spot on the left hand scale for that size and make of rubber tested. This point can then be used to work the nomogram in the same way as in the previous example to give 'breaking turns' for any size (number of strands) and any motor length in that particular rubber.

Note that this marked point on the extreme left hand scale will probably be quite distant from the 'nominal size' spot for the same size of strip and that the maximum turns scale will now read *breaking turns* or absolute maximum turns rather than 'safe maximum'.

Further rubber sizes, or different makes, can be 'calibrated' in this manner, related to actual 'destruction test' figures. Once the nomogram scales have been lined up in this manner for any size of test motor they will give theoretically correct results for any other size of motor in that same rubber.

For the mathematically minded, maximum turns is inversely proportional to the square root of the total cross section of the motor, or

$$\text{Maximum turns} = \frac{K}{\sqrt{A}}$$



where K is a coefficient depending on the quality and condition of the rubber and A is the total cross section (strip-size x number of strands).

Typically the value of the coefficient 'K' for good quality aero strip is between 9.2 and 10.0 As an overall figure, and to reduce the calculated maximum turns to a 'safe' rather than 'breaking' figure, a value of K ~ 8.65 has been adopted for the nomogram.

The method of recalibrating the nomogram against test figures for any particular specimen of aero strip Is equivalent to adjusting the 'K' factor consistent with the test results obtained.

WAKEFIELD MOTOR NOMOGRAMS

This comprises the three vertical scales enclosed within the chain. dotted 'box', Ignore the part of the reference line which runs through the box as this is used with the main nomogram only.

The lefthand scale gives standard rubber sizes, immediately opposite which can be read the equivalent length in feet of 40 grams of lubricated rubber in that size. Connecting across to the number of strands used in the motor (right hand scale) the made up motor length in that size rubber and that number of strands can be read off the centre scale.

Example: to find the length of rubber and made up motor length for a 12 strand Wakefield motor in 1/4 x 24 strip. Answer: length of rubber strip = 19.2 feet, made up motor length (12 strands) -=19.2 ins.

Note, however, that this does not necessarily give an exact solution since rubber weight may vary slightly for the same nominal size of strip. The left hand scale of the nomogram should therefore be used to estimate the length of strip required to make a 40 gram motor and the result checked by actually weighing this cut length. If necessary the length can be adjusted to meet the required weight (40 grams = 1.411 ounces) and the correct value then entered on the nomogram. Note also that the motor weight refers to lubricated rubber weight. This will be roughly 5% greater than the weight of the same length of unlubricated rubber. .

The centre scale gives the made-up motor length before breaking in. After breaking in the unstretched length of the made up motor will be roughly 10 per cent greater than that indicated by the nomogram.

INDOOR MOTORS

From September 1979 Aeromodeller

Here, something more refined is needed. Indoor motors are stretched a lot more than outdoor motors, so the knot is much more highly stressed; also a bulky knot is undesirable for two reasons:

1. it uses up valuable rubber weight and converts it into dead weight.

2. the knot in the motor can catch on the stick fuselage and can therefore cause a bunch to occur in a wound motor. This bunch prevents that part of the motor from unwinding.

A good method but one which is awkward to do without a helper is to stretch the rubber where the knot is to be, using a pair of pliers to grip the ends of the rubber.

Bind the two strands together with cotton or thread, 5--8 turns depending on the thickness of the thread and the knot, then release the tension (See Figure 2). If the rubber has been lubricated, it is advisable to wash off some of the lubricant before re-tying. As a precaution, a drop of cyanoacrylate on the free ends and pinching them together will ensure that the knot stays intact.

A better and easier method was developed over the winter at the low ceiling meetings for use with the new orange Pirelli which seems more susceptible than most others to having the edges cut by the cotton. Tie one loop of cotton round the two strands about 1/16in from the ends (better with lubricated rubber). apply a drop of cyanoacrylate and pinch the ends together. Then tie a single thumb knot and pull tight. No pliers, and no helpers needed. The knot will only fail if the cotton loop is tied too close to the ends. See Figure 3.

As a postscript, I reckon this method will work well on outdoor motors (I would suggest tying the cotton loop 1/4in from the free ends).

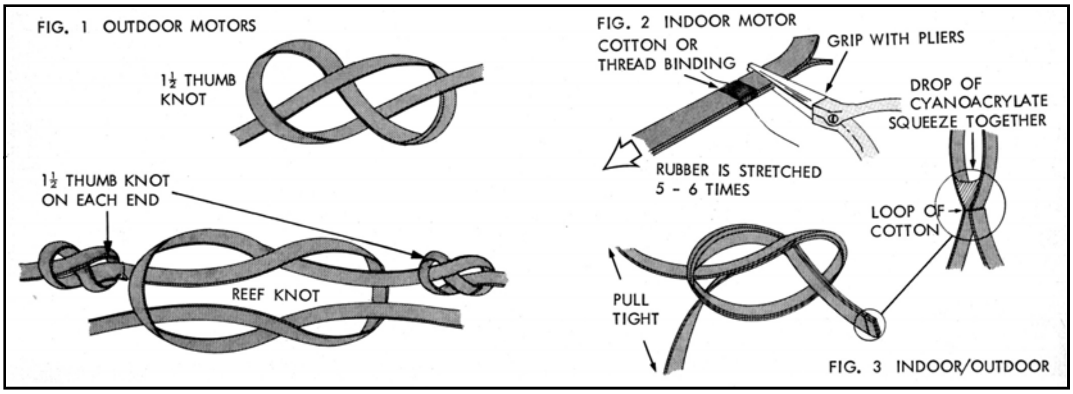


FIG. 1 OUTDOOR MOTORS

FIG. 2 INDOOR MOTOR

FIG. 3 INDOOR/OUTDOOR

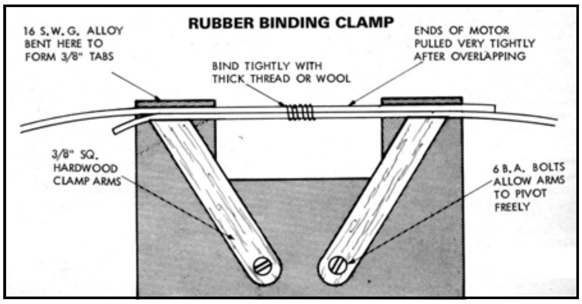
RUBBER TYING CLAMP

By Jack North

Two clamp arms of 3/8in square hardwood are loosely pivotted at one end to a baseplate of 16 s.w.g. aluminium alloy or steel, bent as shown; the other ends of the two arms are cut at an angle so they butt against the upper lip of the baseplate. On my version I have filed serrations into these angled ends and stuck rubber on the lip to provide a tighter grip on the rubber strip. To join the two ends of a motor, overlap them by an inch or so, and pull the double thickness as tight as you can; place one end against the lip of the baseplate and swing the arm up to clamp it into place. The tension of the rubber tends to close the arm tighter against the lip. Keep pulling the double thickness of rubber, stretch it across the gap in the baseplate and swing the other arm up to keep the lapped joint taut; with both hands free you can now tightly bind the joint with half a dozen turns of wool or thread. You may care to add a drop of cyano-acrylate to the bound rubber, before swinging the clamp arms outwards to free the completed motor.

Lubricant is important for improving the performance of rubber and extending its life. Water is quite a good one but would get squeezed out in practice; if you need to cut rubber with a knife the job is far easier if the blade is kept wet. This is why tyre punctures occur more frequently in the rain, and why wheel adhesion on cars is reduced, especially when car tyres used natural rubbers rather than the butyl ones common today.

Some people favour castor oil (the medicinal type, rather than the fuel component, which often contains additives), but it is very hard to remove from a motor if you need to join a broken strand, and even harder to get off hands. Silicone-based surgical lubricants like KY have been used by some people, but the rubber tends to look dry and strands break uncomfortably often. Soft soap and glycerine is the lubricant that many contest flyers use; roughly equal parts are boiled together until the result is about the viscosity of gear oil on a cold day. Too thick a lubricant will be hard to spread over all surfaces of the rubber, while a thin one will spray around inside the fuselage rather



than staying on the motor. Try to find the unattractive-looking brown soft soap, which does not contain the green dye that most stocks now have, and which may not be very good for rubber.

I would not advise using washing-up liquid as a rubber lubricant; we did get a letter from a reader who had used it and complained of frequent broken strands. Many of these domestic detergents are petroleum-derived, and are therefore harmful to rubber.

Bear in mind when weighing your rubber for 10 gramme Coupe or P-30 motors or 40 gramme Wakefield ones that rubber lubricant adds weight; I aim for about 9.5 grammes for a dry Coupe motor, which will allow a little tolerance on both your own weighing device and the processors'. The specified rubber weights are for lubricated motors, so don't cut it too close.

As a final word on rubber, do not expect to get any sort of performance from the whiteish elastic strip sold in some model shops; it has no similarity to the rubber used for making the propellers of model aeroplanes go round fast enough to provide a climb. The material you are looking for is brownish, greyish or blackish, and should stretch to about seven times its normal length. For further information on rubber testing and use, refer to one of the definitive articles on the subject, Testing Commercial Rubber, which appeared in the now defunct Model Aircraft magazine in February 1961; photo copies of the three page article are available from Aeromodeller at a cost of 50p.